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OF THE

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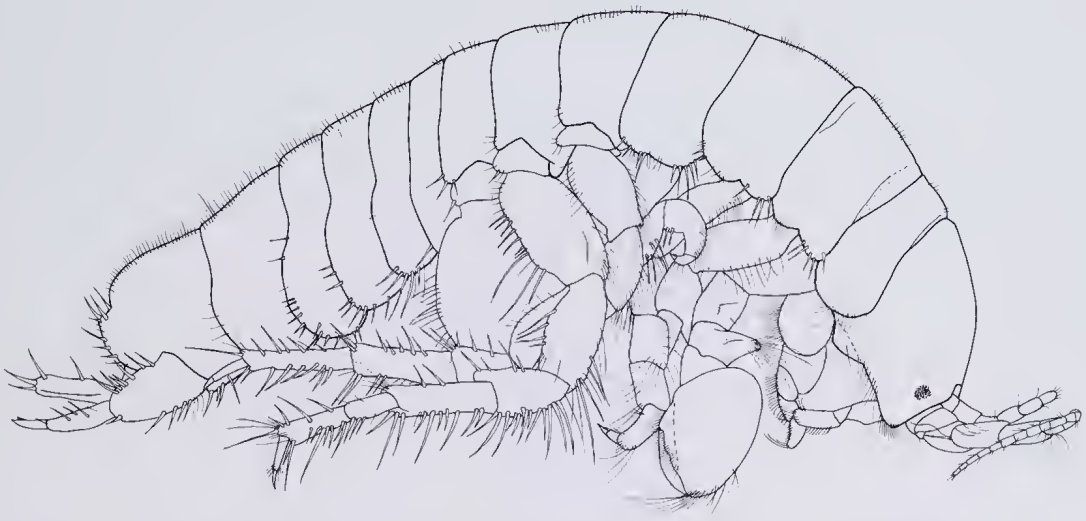

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DISTRIBUTION AND HABITAT OF THE FALSE WATER RAT, *XEROMYS MYOIDES* THOMAS, 1889 (RODENTIA:MURIDAE) IN INTERTIDAL AREAS OF CENTRAL EASTERN QUEENSLAND

DEREK BALL

Ball, D. 2004 06 30: Distribution and habitat of the false water rat, *Xeromys myoides* Thomas, 1889 (Rodentia:Muridae) in intertidal areas of central eastern Queensland. *Memoirs of the Queensland Museum* **49**(2): 487-494. Brisbane. ISSN 0079-8835.

The distribution and habitat preference of *Xeromys myoides* was determined by trapping and searching intertidal habitats along the coastline of central Queensland, between Cannonvale and Cape Palmerston National Park. Patchy evidence of *Xeromys myoides* was found along the full extent of coastline investigated, suggesting that the species may have a wider distribution than previously thought. In the study area, however, the species appeared to be largely restricted to mangrove communities dominated by *Ceriops tagal* and/or *Bruguiera* spp. where it was nevertheless rare, suggesting that complex factors influence its distribution. Nesting appeared to be restricted to tall closed forest dominated by *Ceriops tagal* and *Bruguiera* spp, and adults were more commonly captured in this community. *X. myoides* appeared to inhabit only a small portion of available intertidal habitats within the study area. ❐ *Xeromys myoides, false water rat, central Queensland, habitat, intertidal areas.*

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The false water rat, *Xeromys myoides* is a small, specialised rodent that has been found in coastal intertidal wetlands and some adjacent habitats (Thomas, 1889, McDougall, 1944; Redhead & McKean, 1975; Magnusson et al., 1976; Van Dyck et al., 1979; Van Dyck & Durbidge, 1992; Van Dyck, 1996). It occurs in apparently disjunct coastal populations in Queensland, the Northern Territory and Papua New Guinea (Van Dyck, 1995; Hitchcock, 1998). Although the species' habitat is essentially wetlands, its habits are not truly aquatic (Watts & Aslin, 1981). On North Stradbroke Island (southeastern Queensland) *X. myoides* is an active predator on marine invertebrates, particularly grapsid crabs (Van Dyck, 1996). Magnusson et al. (1976) reported it feeding on marine crabs in the Northern Territory. Several key records of *X. myoides* have been made accidentally e.g. at Melville Island, during estuarine crocodile surveys (Magnussen et al., 1976) and at Myora Springs, North Stradbroke Island (Van Dyck & Durbidge, 1992). Given its habitat and dietary preferences, *X. myoides* is unlikely to be detected by most small mammal survey techniques. Its apparent rarity may be a reflection of this (Van Dyck, 1996; Watts & Asplin, 1981).

The species is listed as vulnerable (Anon, 1994, 1999), however, a recent review of the conservation status of native rodents in Queensland (Dickman et al., 2000) proposes that *X. myoides* be considered endangered due to its apparently small population size, downward trends in abundance and distribution, and presence of threatening processes.

Mackay, (in central eastern Queensland), is the type locality for *X. myoides* (Thomas, 1889). Additional records for Mackay were reported in 1944 by McDougall and in 1982 (Anon.) from Proserpine. The only recently recorded capture within the study area was of a single animal south of Mackay in 1998 (Van Dyck, unpublished data). Several early records were obtained from freshwater sedgelands adjacent to intertidal areas. Within the study area these habitats are now rare, often weed infested and geographically restricted due to land development.

Van Dyck (1996) recorded that no significant foraging by *X. myoides* took place within freshwater habitats on North Stradbroke Island. Given this, freshwater areas were not considered within the current study which aimed to clarify current patterns of distribution and broad habitat utilisation within intertidal habitats in central Queensland (Fig. 1).

MATERIALS AND METHODS

A broad analysis of intertidal communities and their geographical extent in the study area was performed using available intertidal vegetation

mapping (Anon, 2002). Potential habitat of *X. myoides* within the study area was identified using descriptions of known habitat on North Stradbroke Island (Van Dyck, 1996), and central Queensland communities considered to provide suitable habitat by Steve Van Dyck, (pers comm, 1998). A capture of *X. myoides* within the study area by VanDyck immediately prior to this study, assisted initial habitat identification. Mapping of mangrove communities within the study area (Winter & Wild, 1995) and aerial photography were used to select a sample of accessible mangrove communities for field inspection. The vegetation at each site was allocated to one of 7 types. These vegetation types make up 99% of the inter-tidal vegetation communities in the area.

Selected sites were investigated during January-October 1999. Each site was intensively searched for nesting and/or feeding signs of *X. myoides*. Site searches extended approximately 100m in radius around a given point on the supra-littoral margin of the mangrove community. Field inspections sought to locate termitarium-like mounds (Van Dyck (1992, 1996; Van Dyck & Gynther, 2003), mounds associated with buttress roots (Magnusson et al., 1976) and simple tunnels built into supralittoral banks (Van Dyck, 1996). Structures thought to be nests were carefully probed with light gauge wire or mangrove twigs (diameter <5mm) to determine if they contained hollows that could have been nesting chambers or burrow complexes. Hollow sections within such structures could be readily felt by a reduction in pressure needed to insert probes. Nesting structures were also tentatively attributed to *X. myoides* if feeding middens were located near entrance burrows or in close association with a suspected mud structure. Caution was taken to avoid confusing *X. myoides* nests with other mud structures such as those constructed by the mangrove lobster (*Thalassina anomala*) or other mangrove crustaceans, or with deposits of mud naturally accumulated around mangrove tree roots by hydrological action.

Field searches concentrated largely on locating the remains of grapsid crabs having a carapace width of up to approximately 20mm (Van Dyck, 1996).

Searches also focussed on locating 'middens' composed of decapod remains attributable to *X. myoides*. Some middens containing the partially crushed remains of the mud whelk, *Telescopium telescopium* were attributed to the much larger *Hydromys chrysogaster* or the Black Rat (*Rattus rattus*). Middens that contained significantly damaged, heavy crab carapace or appendages (especially claws) were also attributed to *H. chrysogaster* or *R. rattus*. Searches for feeding signs were made between the level of highest astronomical tide and low water level, preferably during neap tidal cycles.

FIG. 1. Study area covering intertidal habitats in central-eastern Queensland, form Cannonvale to Cape Palmerston.

Spotlighting, using low powered lights (Petzl 4.5v headlamps with standard bulb and/or 30 watt handheld spotlights) was abandoned as a cost-effective survey technique with only one animal observed for 32 person hours searching. No tracks or trackways could be attributed to *X. myoides*.

Sites inspected were classified according to the evidence of *X. myoides* present. Class 1 sites contained structures assumed to be nests. Class 2 sites contained feeding remains that may have been left by *X. myoides* but no nest structures. Class 3 sites contained no evidence of the presence of *X. myoides*. Trapping was conducted within a sample of Class 1 sites to confirm the presence of *X. myoides*. One locality containing Class 2 sites was trapped extensively in response to a sighting of *X. myoides* while spotlighting. A selection of Class 2 and 3 sites was also trapped regardless of assumptions based on signs observed. The latter sites were selected as a sample of different mangrove communities occurring within the study area.

TABLE 1. Major inter-tidal vegetation communities within the study area.

Vegetation Community	Percentage Extent within the Study Area
Closed shrub-land of *Aegiceras corniculatum*. This community is rare within the study area and typically occurs as a thin linear fringe on the landward side of other communities.	< 1%
Open to closed forest of *Avicennia marina*. This community occurs at both landward and seaward margins, and is often structurally variable at any given location.	3%
Open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. Two forms of this community are readily recognised. One forms a tall (to 12m) forest near the supralittoral zone and tends to contain *Bruguiera* spp. as co-dominants or rarely, dominant canopy species. The second is a low open to closed forest or shrub-land occurring near the supralittoral margin, or on low rises surrounded by saltpan.	25%
Mixed species closed forest.	13%
Closed forest of *Rhizophora* spp, typically *R. stylosa*. These forests typically occur on seaward margins or in areas close to, or within regular tidal flows.	31%
Saline grassland (dominated by *Sporobolus virginicus*). Saline grasslands are typically supralittoral communities that grade into adjacent samphire flats and/or terrestrial vegetation.	3.5%
Salt-pan and samphire flats. The level to which salt-pans are vegetated by samphire is highly variable and in many areas no vegetation is present.	23%

Type A 'Elliot' traps were baited with halved Western Australian pilchards and placed in the intertidal zone. Traps were typically placed alongside fallen timber, amongst buttress roots and inside fallen logs. Traps were also placed near nests or middens. A trap-line consisted of 20 traps placed approximately 10m apart. Trap-lines were located to ensure that all structural and floristic variants of the mangrove community were sampled. Typically traps were located parallel to the coastline and between the supra-littoral zone and the low water mark. Thin white cotton string was laid along the trap line at waist height to facilitate easy recovery of the traps. All sites were trapped for a minimum of four nights with a minimum of one trap-line (ie 80 trap nights) unless a capture was made earlier. Actual number of traps used was dictated by size of the site. Preference was given to setting trap-lines around daytime high tides when following night high tide levels were lower. This approach greatly reduced the risk of inundation and drowning of captured animals. In some cases it was possible to accurately gauge the likely extent of the night high tide by examining the level of ground moistened by previous tides.

All animals caught were weighed, and measured. Each animal was assigned to an age class on weight, and sexed on anal-urogenital distance (Van Dyck, 1996). Each animal was then immediately released at the point of capture and its behaviour observed.

RESULTS

The study area contains approximately 39,384 hectares of inter-tidal vegetation communities (Anon, 2002). Approximately 99% falls into 7 readily recognizable types (Table 1). During January 1999 and October 1999 125 sites at 35 localities were inspected for signs of *X. myoides*. Each site was allocated to one of 7 vegetation types. No evidence of 'termitaria' type nesting structures was observed at any site. Nesting structures attributed to *X. myoides* consisted of mud ramps constructed between the buttress roots of *Ceriops tagal* or more commonly *Bruguiera* spp. Nests were observed on living trees, dead standing trees and occasionally, stumps or large root masses which had toppled over. Nests sometimes exhibited fresh plastering of mud on their surfaces and often-contained fragments of small crab shell. Often, a number of tunnels with oval-shaped entrances (Van Dyck, 1996) lead into the nest. No ramp was greater than 60cm high. Feeding signs of *X. myoides* typically consisted of clean, disarticulated dorsal crab carapace (Grapsidae) No crab carapace wider than 30mm was found and most were less than 20mm. Other remains of the crab including uneaten appendages often lay close by. Middens consisting of several crab remains were often observed at the base of presumed nesting structures, in sheltered areas between mangrove buttress roots, within hollow logs or adjacent to fallen timber.

Three of the 7 communities were assigned to Class 3 (i.e. no sign of *X. myoides*). These were closed forest of *Rhizophora* spp., closed shrub-land of *Aegiceras* corniculatum, and saltpan/samphire flats. It was concluded that *X. myoides* did not utilise these communities and they were not targeted for trapping. However, given that inside closed forest of *Rhizophora* spp. feeding remains might have been regularly removed or obscured by daily tidal flows, two sites were selected for trapping. This trapping did

TABLE 2. Vegetation types surveyed, classified and trapped.

Community	Time of Survey	No. Sites Inspected	Site Class	No. Sites Trapped	Total Trap Nights
Closed shrub-land of *Aegiceras corniculatum*	May – June 1999	7	3	0	0
Open to closed forest of *Avicennia marina*	Jan - Oct 1999	15	2/3	6	1,289
Open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (tall forest)	Jan – Aug 1999	26	1/2/3	8	490
Open to closed forest of Ceriops tagal +/- *Bruguiera* spp. (low forest)	Apr – Aug 1999	7	1/2/3	5	340
Mixed species closed forest	Jan – October 1999	31	3 rarely 2	2	200
Closed forest of *Rhizophora* spp.	Jan – July 1999	25	3	2	200
Saline grassland	March – May 1999	9	1/3	1	120
Salt-pan and samphire flats	March-May 1999	5	3	0	0
Totals	Jan – October 1999	125		24	2,639

not result in any captures. Three communities were assigned to Class 2 (contained feeding evidence). These were saline grassland, mixed species closed forest, and open to closed forest of *Avicennia marina*. Areas of saline grassland contained signs on only one occasion at 1 of the 9 sites inspected. The grassland at this site was adjacent to a closed forest of *Ceriops tagal* that contained signs both of feeding and nesting. This was the only grassland site trapped. Of the 31 sites containing mixed species closed forests (Table 2), only 2 contained signs attributable to *X. myoides*. Both these sites were trapped. Open to closed forests of *Avicennia marina* contained feeding signs attributable to *X. myoides* at 8 of the 15 sites. One individual was observed while spotlighting in March 1999. Six of the 8 sites that contained feeding signs were trapped, and additional time (31 person hours) was spent spotlighting at the locality where the previous sighting was made. The only community that was allocated to Class 1 (nesting sign present) was closed forest of *Ceriops tagal* +/- *Bruguiera* spp. Although nests were present within both forms of this community, they were more common in tall forests (11 of 26 sites) than in low forests (2 of 7). However, within these communities it was also common to find no nesting sign (15 of 26 sites, and 5 of 7, respectively). Some areas of this community contained no sign attributable to *X. myoides* (5 of 26, and 2 of 7 sites, respectively). Eight tall forests and 5 low forests were trapped.

A total of 2,639 trap nights was spread over 24 sites (Table 3). Captures were usually made on the first night (8 of 11 sites) and on only one occasion (Dunrock West 1) did it take more than two nights for the first capture. Most captures were made within Class 1 sites of tall open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. The exceptions were one capture at a Class 2 site, a low open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (Cape Palmerston 2) and one capture at a Class two, saline grassland site (Dunrock west 1) One tall open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (Class 2) and 2 low open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (Class 2) sites did not yield captures. 1,089 of the 1,289 trap nights in *Avicennia marina* open to closed forest took place at 4 sites within approximately 500m of the spotlighting sighting made in March 1999. In addition, no more sightings of *X. myoides* were made despite 31 person hours of search effort.

The 11 successfully trapped sites yielded 21 animals from 630 trap nights. One animal perished from unknown causes and was forwarded to the Queensland Museum (JM 13850). *X. myoides* was the only small mammal caught. Cane toads (*Bufo marinus*) were captured in small numbers. Although animals were most often captured in the first night, trap success was low, typically; less than 3%. An outstanding exception was the site Freshwater Point East 1, which yielded 10 animals from 40 traps in the first night (i.e. 25% trapping success).

Adults were captured at 5 of 11 sites. 7 of 10 animals captured at Freshwater Point East were adults (4 males, 3 females). All were caught in a 3ha block of habitat (total area < 8ha) surrounded by habitat presumed unsuitable for the species (dry terrestrial vegetation, saltpan and built infrastructure including a sealed road).

Fourteen females and six males were captured in addition to one unsexed individual (Table 4). Pilchard baits were, in most cases, almost fully

TABLE 3. Sites trapped to confirm or otherwise presence of *X. myoides*.

Community	Site/ Site Class	Timing	Trap nights	Captures	Night of capture
Open to closed forest of *Avicennia marina*	Barnes Creek Road East 1 / 2	Jan 1999	429	nil	
	Barnes Creek Road East 2/ 2	Mar 1999	160	nil	
	Barnes Creek Road West 2/ 2	Mar 1999	240	nil	
	Dolphin Heads/ 2	Apr 1999	60	nil	
	Barnes Creek Road West 1/ 2	Jun 1999	260	nil	
	Andergrove / 2	Oct 1999	120	nil	
Open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (tall forest)	Dunrock West 1/ 1	Mar 1999	120	1	3rd
	Freshwater Point East/ 1	Jun 1999	40	10	1st
	Cape Palmerston 1/ 1	Jun 1999	60	1	2nd
	Proserpine River/ 1	Jul 1999	40	1	1st
	Waite Creek/ 1	Jul 1999	40	1	1st
	Eimeo 1/ 1	Aug 1999	40	1	1st
	Bucasia 1/ 2	Aug 1999	120	nil	
	Bucasia 2/ 1	Aug 1999	40	2	1st
Open to closed forest of *Ceriops tagal* +/- *Bruguiera* spp. (low forest)	Bakers Creek 1/ 2	Mar 1999	60	nil	
	Smalley's Beach/ 1	Apr 1999	40	1	1st
	Cape Palmerston 2/ 2	Jun 1999	60	1	1st
	Freshwater Point West 2/ 1	Jun 1999	40	1	1st
	Eimeo 2/ 2	Aug 1999	120	nil	
Mixed species closed forest	Bakers Creek 2/ 2	Mar 1999	60	nil	
	Andergrove 2/ 2	Oct 1999	120	nil	
Closed forest of *Rhizophora* spp.	Funnel Bay/ 3	May 1999	120	nil	
	Shute Harbour/ 3	May 1999	80	nil	
Saline grassland	Dunrock West 2/ 2	March 1999	120	1	1st

consumed by trapped animals. The fleshy fillets either side of the spine were consumed by captive animals leaving the fine skeletal structures neatly intact. Released animals quickly entered tunnels associated with nests or found refuge in crab holes.

DISCUSSION

The study area contains approximately 39,384ha of inter-tidal vegetation largely dominated by mangrove communities and associated saline grasslands. A number of studies in other regions, notably the benchmark work of Van Dyck (1996), found these communities to be suitable habitat for *X. myoides*. In this study *X. myoides* was, with few exceptions only captured within open to closed forests of *Ceriops tagal* +/- *Bruguiera* spp. Although the species was trapped once within an area of marine couch, a closed forest of *Ceriops tagal* and *Bruguiera* spp. abutted it and traps were laid less than 20m from the mangrove forest. Despite site surveys and in addition to incidental observations made over 9 months, no sign of *X. myoides* (either nesting or feeding) was found within marine couch saltmarsh.

A single individual was observed within a closed forest of *Avicennia marina*. However, despite intensive searching and trapping, no additional records were obtained in *A. marina* forest. Van Dyck (1994) noted that *X. myoides* could travel relatively large distances at night (up to 2.9km). As such, the animal observed may not have actually resided in the *A. marina* forest. It appears that on the central Queensland coast; open to closed forests of *Ceriops tagal/Bruguiera* spp. form the core habitat of *X. myoides*. This vegetation type makes up approximately 25% (approx. 9,887ha) of the geographical extent of inter-tidal vegetation in the study area. However, not all of the open to closed forests of *Ceriops tagal/ Bruguiera* spp surveyed were found to be inhabited by *X. myoides*. Site surveys yielded no evidence of the species within some forests of this type, and trapping failed to capture animals on a number of occasions even when feeding signs (but not nesting signs) were evident. While in most cases, no obvious impacts on the

TABLE 4. Details of animals caught by this study.

Site	Weight (gm)	Tail (mm)	Body (mm)	Foot (mm)	Ear (mm)	Anus- urogenital pouch (mm)	Sex	Ad/ Juv/ SubAd
Dunrock West 2	30	85	77	25	8.8	8.0	f	Ad
Dunrock West 1	Not rec.							
Smalley's Beach	29.5	75.5	105.5	23.7	8.5	8.9	f	Subad
Cape Palmerston 2	22	62.5	77.5	22	9.1	14.4	m	Juv
Cape Palmerston 1	30	73.9	104.3	22.6	7.3	8.0	f	Subad
Freshwater Point East	31	80.5	92.4	23.9	8.8	8.6	f	Subad
Freshwater Point East	30	73.9	87.9	23	8.8	5.9	f	Subad
Freshwater Point East	51	94.3	108.3	24.1	8.8	18.9	m	Ad
Freshwater Point East	37	73.3	105	24	7.7	14.4	m	Ad
Freshwater Point East	46	84.4	105.4	23.2	8.8	8.8	f	Ad
Freshwater Point East	31	87.3	105.5	21.9	7.1	14.4	m	Ad
Freshwater Point East	30	85.4	111	22.6	8.8	8.9	f	Ad
Freshwater Point East	55	86.2	114	24.4	8.5	20.1	m	Ad
Freshwater Point East	31	84.4	112.2	23.1	7.1	9	f	Ad
Freshwater Point East	30	78.4	89.8	23.1	7.3	12.5	m	Subad
Freshwater Point West 2	46	81.5	103.2	23	7.5	8.9	f	Ad
Proserpine River	25	68.3	86.2	21.7	7.7	7.9	f	Juv
Waite Creek	24	71.1	80.9	20.0	6.5	6.8	f	Juv
Eimeo 1	44	80	99.6	22.9	9.3	8.1	f	Ad
Bucasia 2	51	94.5	104	23.1	9.1	8.1	f	Ad
Bucasia 2	37	71.2	103.6	22.9	8.9	8.9	f	Ad

mangrove forest were evident, clearing of vegetation to the mangrove edge, alteration of overland water flows (i.e. concentration of stormwater run-off from adjacent urban areas) and disposal of rubbish, were obvious.

The absence of *X. myoides* captures when feeding signs are present is not without precedent. Local extinctions have been reported elsewhere; Hobson (pers comm) on Fraser Island and on the central Queensland coast (Ball & Ball pers obs). Conversely, capture of animals in areas where previous trapping surveys yielded nothing has been reported by Woinarski et al. (2000). The possible reasons for such temporal changes in distribution remain unclear.

This study can throw limited light on the preference of *X. myoides* for closed forests of *Ceriops* tagal +/- Bruguiera spp, or the finer scale distributional patterns within this community. Lee (1998) noted that grapsid crabs are generally more abundant at the supralittoral zone and Woinarski et al. (2000) suggested that the crabs may affect local distributional patterns. On the central Queensland coast, *Ceripos tagal* and/or *Bruguiera* spp typically dominate this zone. Although quantitative surveys were outside the scope of this study, casual observations indicate a difference in crab populations (demonstrated by the density of crabholes) between various sites even within the same mangrove community. There may be a link between the size of grapsid crab populations and presence of *X. myoides* in the study area. There may be dietary preference by *X. myoides*, for a particular species or assemblage of species. Grapsid crabs are important consumers of mangrove propagules (Smith et al., 1991) with each species of crab having a dietary preference for the propagules of particular mangrove species (Lee, 1998). The number of grapsid crabs is therefore likely to be higher in mangrove communities that are actively producing propagules, and some species may be more numerous in some mangrove communities. *X. myoides* distribution patterns between and within communities may reflect seasonal changes in habitat value.

Nesting strategies employed by *X. myoides* in the central Queensland do not appear to include the termitaria type nests ascribed to the species elsewhere. Despite intensive searches, no termitaria like nesting structures were positively identified by this study. Instead it appears that *X. myoides* in central Queensland uses mud ramp

nests constructed amongst buttress roots of mangrove trees. Mud ramp nests were only observed in association with buttress roots of *Ceriops tagal*, and more commonly, *Bruguiera parviflora* or *B. gymnorrhiza*. Several mud ramp nests observed were almost identical, at least from the outside, to that described by Magnusson et al. (1976). However, some were not as distinctive and only breaching the nest would have confirmed its use by *X. myoides*. No other nesting strategies were detected within the study area, although nests constructed inside supralittoral banks via simple tunnels may easily have gone unnoticed. Reasons for the difference in nest types between central Queensland and elsewhere are unclear. However, the moist wallum, heath, sedgeland and freshwater influences along mangrove ecotones (Van Dyck, 1996), were not present to any large degree at any sites where captures were made in this study. Instead, there was typically a sharp and distinct ecotone between mangroves and dry sclerophyll woodlands and/or saltpan. Van Dyck (1996) suggested that *X. myoides* has a need to dissipate excess heat and may do so by occupying saturated nesting mounds, and by 'puddling' during foraging excursions. Where *X. myoides*, occurs in central Queensland, the only areas in which a nest could remain saturated, or even moist, is within the mangrove forest. Alternatively, construction of mud ramp nests may be an energy saving strategy. Mud ramp nests were always observed associated with buttress roots that effectively formed at least one side of the nest. Presumably, using an existing structure as the basis of a nest would decrease the amount of energy required for its construction and maintenance.

Van Dyck (1996) recorded a mean trapping success rate of 11.7% on North Stradbroke Island. With the notable exception of the apparently aberrant site, (Freshwater Point East @ 25%) trapping on the central Queensland coast averaged only a 1.86% success rate. One possible reason for this may be that habitats within central coastal Queensland may not be as densely populated as those on North Stradbroke Island, and/or that home ranges may be larger in central Queensland.

Although data are limited, initial indications are that tall closed forests of *Ceriops tagal/ Bruguiera* spp. represent preferred habitat for adults as they more often contain nests. Most captures of adults took place within these tall forests. Low forest of *Ceriops tagal/ Bruguiera* spp. rarely contained nests and trapping resulted in only one adult capture.

All animals captured fell into size and weight ranges described for North Stradbroke Island (Van Dyck, 1996). Larger males also had faint 'spotting' similar to that described. With the exception of patterns of habitat use and nesting, there appears to be no obvious behavioural or morphological differences between *X. myoides* in central Queensland and other areas. Patterns of habitat use, and nesting strategies, in central Queensland are considered local adaptations to ecological and physiographical features. Because of the difficulty in consistently recognising nests and the ambiguity of feeding signs, observational site survey alone is not considered to reliably confirm the presence of the species in central Queensland although observational site surveys may be useful elsewhere.

IMPLICATIONS FOR CONSERVATION

Previous studies, notably that of Van Dyck, (1996) suggest that *X. myoides* can make use of a wide range of intertidal habitats. However, this study found that, in central Queensland, the species makes significant use of only 25% of available intertidal habitat. The habitats used are most often directly adjacent to terrestrial areas that are subject to ongoing disturbance, modification and clearing, aquaculture and housing. The downstream effects of these changes on mangrove communities and *X. myoides* are not yet quantified but remain a significant concern. Feral pigs, foxes and both feral and domestic cats are common throughout the central Queensland coast and their impact, as predators on *X. myoides*, is likely to be significant. *X. myoides* was found throughout the study area. Similar habitat to that within the study area extends further north and south. It is therefore highly likely that the range of the species, within central Queensland will be extended with further survey effort. However, it appears that the species occurs in low numbers within only a small portion of broadly suitable habitat. There seems to be little justification for downgrading the species' threatened status.

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LITERATURE CITED

ANONYMOUS, 1982. Environmental impact assessment of the Condor oil shale project. Unpubl. report. (Kinhill & Associates: Brisbane).

ANONYMOUS, 1994. Nature conservation (Wildlife) regulation. (Queensland Government: Brisbane).

ANONYMOUS, 1999. Environmental Protection and Biodiversity Conservation Act Commonwealth of Australia. (Australian Government: Canberra).

ANONYMOUS, 2002. 1:100,000 coastal wetland vegetation mapping for Queensland including mangrove communities, saltpans and saline grasslands. Queensland Department of Primary Industries.

BALL, D.S. & BALL, T.M. The abundance of *Xeromys myoides* in central coastal Queensland (in prep).

DICKMAN, C.R. LEUNG, L.K-P. & VAN DYCK, S.M. 2000. Status, ecological attributes and conservation of native rodents in Queensland. Journal of Wildlife Research 27: 333-346.

HITCHCOCK, G. 1998. First record of the false water-rat, *Xeromys myoides* (Rodentia: Muridae), in New Guinea. *Science in New Guinea* 23: 141-144.

LEE, S.Y. 1998. Ecological role of grapsid crabs in mangrove ecosystems: a review. Journal of Marine and Freshwater Research 49: 335-343.

MAGNUSSON, W.E., WEBB, G.J.W. & TAYLOR, J.A. 1976. Two new locality records, a new habitat and a nest description for *Xeromys myoides* Thomas (Rodentia: Muridae). Journal of Australian Wildlife Research. 3: 153-157.

McDOUGALL, W.A. 1944. An investigation of the rat problem in Queensland canefields. 2. Species and general habits. Queensland Journal of Agricultural Scicce 1:48-78.

REDHEAD, T.D. & McKEAN, J.L. 1975. A new record of the false water rat, *Xeromys myoides* Thomas, 1889 from the Northern Territory of Australia. Australian Mammalogy 1: 347-354.

SMITH, T.J., BOTO, K.G., FRUSHER, S.D. & GIDDENS, R.L. 1991. Keystone species and mangrove forest dynamics: the influence of burrowing by crabs on soil nutrient status and forest productivity. Estuarine, Coastal and Shelf Science 33: 419-432.

THOMAS, O. 1889. Description of a new genus of Muridae allied to *Hydromys*. Proceeding of the Royal Zoological Society of London 1889: 247-250.

VAN DYCK, S. 1994. The rats at neptune's table. Australian Natural History 24(8): 30-37.

1995. False weater-rat. In Strahan, R. (ed.) The mammals of Australia. (Australian Museum/ Reed New Holland: Sydney).

1996. *Xeromys myoides* Thomas, 1889 (Rodentia: Muridae) in mangrove communities of North Stradbroke Island, Southeast Queensland. Memoirs of the Queensland Museum 42(1): 337-366.

VAN DYCK, S., BAKER, W.W. & GILLETTE, D.D. 1979. The false water rat *Xeromys myoides* on Stradbroke Island, a new locality in southeastern Queensland. Proceedings of the Royal Society of Queensland 90: 85.

VAN DYCK, S. & DURBIDGE, E. 1992. A nesting community of flase water rats *Xeromys myoides* on the Myora sedgelands of North Stradbroke Island. Memoirs of the Queensland Museum 32(1): 374.

VAN DYCK, S. & GYNTHER, I. 2003. Nesting strategies of the Water Mouse *Xeromys myoides* in southeast Queensland. Memoirs of the Queensland Museum 49(1): 453-479.

WATTS, C.H.S. & ASLIN, H.J. 1981. The rodents of Australia. (Angus & Robertson: Sydney).

WINTER, D. & WILD, A. 1995. Current distributions and historical comparisons of intertidal vegetaion communities and saltpans in the Mackay region (Shoal Point to Hay Point). Unpublished report of Queensland Department of Primary Industries.

WOINARSKI, J.C.Z., BRENNAN, K., DEE, A., NJUDUMUL, J., GUTHAYGUTHAY, P. & HORNER, P. 2000. Further records of the false water rat *Xeromys myoides* from coastal Northern Territory. Australian Mammalogy 21: 221-223.

REVISION OF THE NEW AUSTRALIAN GENUS *HOLASTERON* (ARANEAE: ZODARIIDAE): TAXONOMY, PHYLOGENY AND BIOGEOGRAPHY

B.C. BAEHR

Baehr, B.C. 2004 06 30: Revision of the new Australian genus *Holasteron* (Araneae: Zodariidae): taxonomy, phylogeny and biogeography. *Memoirs of the Queensland Museum* **49**(2): 495-519. Brisbane. ISSN 0079-8835.

This revision of the endemic Australian zodariid *Holasteron* gen. nov. reveals 16 new species belonging to three species-groups. *H. aspinosum*-group: *H. aspinosum*, sp.nov. (♀,♂), *H. kangaroo*, sp. nov. (♀,♂) and *H. hirsti*, sp. nov. (♀,♂). *H. spinosum*-group: *H. esperance*, sp. nov. (♂), *H. lumphreysi*, sp. nov. (♀,♂), *H. pusillum*, sp. nov. (♂), *H. reinholdae*, sp. nov. (♀,♂) and *H. spinosum*, sp. nov. (♀,♂). *H. aciculare*-group: *H. aciculare*, sp. nov. (♀,♂), *H. driscolli*, sp. nov. (♀,♂), *H. flinders*, sp. nov. (♂), *H. marliesae*, sp. nov. (♀,♂), *H. perth*, sp. nov. (♀,♂), *H. quemuseum*, sp. nov. (♂), *H. stirling*, sp. nov. (♀,♂) and *H. wamuseum*, sp. nov. (♂). Both sexes were available for 11 species.
The possible relationships of the species-groups, are analysed with Hennig86, NONA and also reconstructed using the original Hennigian method. All three methods indicate that *Holasteron* gen. nov. is monophyletic and consists of three different species-groups. *H. aspinosum*-group can be seen as the basal sister-group of *H. spinosum*- and *H. aciculare* group. ❐ *Zodariidae, Holasteron, new species, Australia.*

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The arachnid Zodariidae is one of the most dominant ground-living spider families (Churchill, 1998) in Australia. Most species can be recognised easily by their bright yellow or orange spots on a dark brown abdomen and their white, black and orange annulated legs.

With an estimated 350-400 species, Australia has one of the richest known zodariid faunas worldwide. Only 19 species were described for the Australian continent in the first 130 years of investigation. In the last 10 years, 55 new species have been described from Baehr & Jocqué (1994, 1996, 2000), Jocqué & Baehr (1992, 2001). With funding by the Australian Biological Resources Study Participatory Program, 92 additional new species were described in the last two years (Baehr & Jocqué 2001; Baehr 2003a,b,c; Baehr & Churchill, 2003).

Holasteron gen. nov. with 16 new species, belongs to the large *Asteron*-complex (Baehr & Jocqué, 1996) first described from 2 species by Jocqué (1991).

Like all other described genera of the *Asteron*-complex, *Asteron*, *Basasteron*, *Cavasteron*, *Euasteron*, *Leptasteron*, *Minasteron*; *Pentasteron*, *Phenasteron*, *Pseudasteron*, *Subasteron*, *Spinasteron* and *Tropasteron* (Baehr 2003a,b, Bachr & Churchill, 2003, Baehr & Jocqué 2000, 2001, Jocqué 1991, Jocqué & Baehr 2001) *Holasteron*, mentioned in Baehr & Jocqué (1996) as the *Asteron howi*-group, is endemic to Australia.

MATERIAL AND METHODS

Descriptions were generated with the aid of Intkey (Dallwitz *et al.* 1998). Maps are created with Biolink version 1.5 (CSIRO Entomology, Canberra http://www.biolink.csiro.au/).

Drawings were done of the body, right palp and epigyne. All measurements are in millimetres. Scales of drawings are body (1mm), palp (0.5mm), epigyne (0.1 mm). Descriptions of spination and colour patterns follow that in the revision of *Euasteron* (Baehr, 2003a).

Character abbreviations: ALE, anterior lateral eyes; AME, anterior median eyes; cl/cw, carapace length/width; CD, copulatory duct; CO, copulatory opening; DTA, distal tegular apophysis (in previous papers called dorsal tegular apophysis); DtiA, dorsolateral tibial apophysis; E, embolus; EP, external prong on dorso-retrolateral tibial apophysis; IP, internal prong on dorso-retrolateral tibial apophysis; MS, retrolaterally directed, spine-shaped membrane at the base of DTA; PE, prolateral extension of DTA; PLE, posterior lateral eyes; PME, posterior median eyes; PR, prong as ventral part of RDTA; PTF, prolateral transparent field on embolus base; RDTA, retrolateral extension of DTA; RE, retrolateral extension on cymbial flange; S, spermatheca; sl/sw, sternum length/ width; SP, sperm duct; TBE, transbasal area of embolus; TF, transparent field on embolus base; VtiA, ventral tibial apophysis.

Institutional abbreviations: AM, Australian Museum, Sydney ; CAS, California Academy of Science; SAM, South Australian Museum, Adelaide; QM, Queensland Museum, Brisbane; WAM, Western Australian Museum, Perth.

SYSEMATICS

Holasteron gen. nov.

TYPE SPECIES. *Holasteron aciculare* sp. nov.

ETYMOLOGY. Greek *holo-*, entire, all; this genus of the *Asteron*-complex is found in all states of Australia except the Northern Territory.

DIAGNOSIS. Apart from the characters typical for the *Asteron*-complex, species of *Holasteron* are recognised mainly by characters from the male palp (Figs 3, 7A,B, 8A,B) and also by AME beeing equal or larger than others (Figs 1,2). Cymbial flange with long retrolateral extension (RE) bent inside. Cymbium with 4 or more distal spines, sperm duct (SP) weakly S-shaped, not crossing TF; embolus base elongated at least 2.5 as long as wide, with additional prolateral transparent field (PTF), embolus thin, semicircular, conducted by big ear-shaped DTA.

DESCRIPTION. Medium-sized spiders (2.80-7.00) with finely reticulated tegument. Carapace at frontal part broad, widest at coxae III. Profile, the highest point between fovea and PME (Fig. 1B, 2B).

Colour: Carapace yellow to sepia brown; sternum yellow to sepia brown; chelicerae yellow to medium brown; maxillae and labium pale to medium brown, distally white; abdomen medium to dark brown with or without scutum; with 1-3 pairs of white spots on anterior part and 1-3 in front of spinnerets, or with pale chevrons; laterally and ventrally pale to dark brown; legs yellow to medium brown with or without colour pattern.

Eyes (Figs 1A-C, 2A-C) in three rows (2-4-2). Only ALE in first row, AME (in the middle) and PLE in second, third only PME. AME equal to or larger than the others. Clypeus straight, between 3.6 and 4.6 times diameter of ALE high. Chilum single. Chelicerae as usual for family with a few hairs in front and dense row on distal promargin; no teeth. Maxillae and labium triangular; sparsely haired; Maxillae with anteromesal scopula, no serulla. Sternum heart-shaped with straight anterior margin, shiny or finely reticulated.

Legs with few spines on pairs I, II, more numerous on III, IV. Metatarsal preening brush on Mt II and III poorly developed. Paired tarsal claws with numerous (10-14) teeth on inner side (Fig. 4C). Unpaired claw toothless, on very small

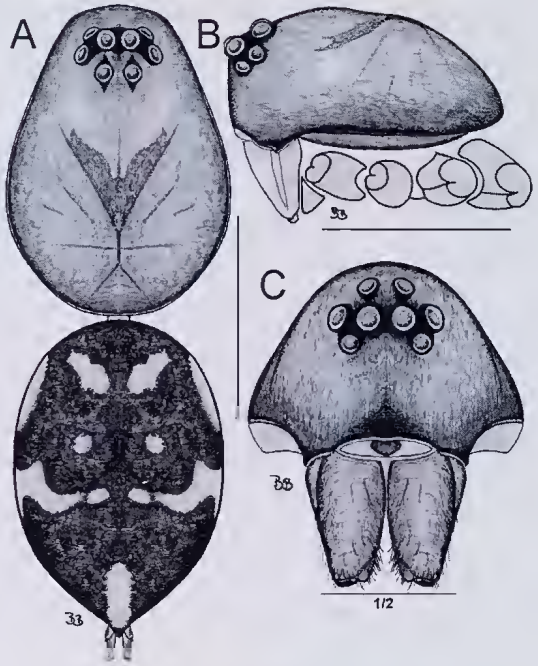

FIG. 1. *Holasteron pusillum*. A, body dorsal, B,C, carapace; B, lateral; C, frontal. Scale 1mm.

onychium. Female palpal claw strong with 5-7 teeth (Fig. 4A,D).

Abdomen oval, without sigilla. Spinnerets: AS short, conical, with very short distal segment; MS and PS tiny, situated in I transverse row behind AS. Colulus represented by group of setae. Tracheal spiracle slit-like covered by posterior sclerotised lip (Fig. 4B).

Male palp. (Figs 3, 7A,B) Cymbial flange with inside bent semicircular extension (RE). Cymbium with 4 or more dorsal spines, with or without retrobasal spine (Fig.13A). With or without retrolateral directed MS (without: *H. aspinosa*-group, well developed: *H. spinosum*- and *H. aciculare*-group); PE short (*H. apinosa*-, *hirsti*-group), not reaching tibia, longer, (reaching tibia: *H. spinosum*-group) or extremely elongate (longer than cymbium and tibia in *H. aciculare*-group; RDTA with sharp tip and with or without prong, (from ventral view, tip is lying behind prong in *H. aciculare*-group); embolus base elongated with additional prolateral transparent field PTF connected TF distally, embolus thin, semicircular, conducted by big ear-shaped DTA; sperm duct weakly S-shaped, not crossing TF. Tibia: VTiA short or long, straight or hooked, with or without incision; DtiA, IP reduced to tiny knob, EP with distal saddle in scaled structure

(Fig. 13B). Femora with one or two strong spines dorsally.

Epigyne. (Fig. 7C,D) The basal structure of the epigyne with two lateral sickle-shaped or one semicircular CO, with or without inverted u-shaped sclerotised tubes, with few or numerous coiled CD, ending in helical sausage-shaped or ellipsoid S, is similar to the epigynes of the *Euasteron* and *Spinasteron* species.

DISTRBUTION. SE, S and SW Australia.

KEY TO SPECIES-GROUPS AND SPECIES OF *HOLASTERON* MALES

1. Male palp without MS (Fig. 3A,B) . . . . . (*H. aspinosum*-group) - 2
   Male palp with MS (Fig. 3C,D). 4
2. Palp, RDTA tip tripartite, with distal and basal directed prong (Fig. 7A,B) . . . . . *H. hirsti*
   Palp, RDTA with distally bent prong (Fig. 5A-D) . . . 3
3. Palp, RDTA with basally directed tip (Fig. 5A,B) . . . . . *H. kangaroo*
   Palp, RDTA with distally bent tip (Fig. 5C,D) . . . . . *H. aspinosum*
4. Palp ventral view, RDTA prong not overlaping tip or absent (Fig. 8D, 10B) . . . . . (*H.spinosum*-group) - 5
   Palp ventral view, RDTA prong overlaping tip (Fig. 12B) . . . . . (*H. aciculare*-group) - 9
5. Abdomen dorsal dark brown with pale chevrons (Fig. 1,2A) 6
   Abdomen dorsal dark brown with 2 or more pairs of pale dots on top and 1 in front of the spinnerets 7
6. RDTA with only sharp tip and without prong (Fig. 8A,B) . . . . . *H.pusillum*
   RDTA with sharp tip and small flattened prong (Fig. 10A,B). . . . . *H. reinholdae*
7. Legs pale without colour pattern, RDTA with only sharp tip, MS tiny (Fig. 9A,B). . . . . *H. humphreysi*
   Legs clearly annulated 8
8. Legs, femora I-IV proximal part white, distal part pale brown, MS tiny (Fig. 8C,D) . . . . . *H. esperance*
   Legs, femur 1 dark brown with white lateral spot, II-IV proximally white distally dark brown, MS bigger (Fig. 11A,B) . . . . . *H. spinosum*
9. Carapace yellow with dark cephalic area, abdomen dorsal dark brown with one pair of white spots on posterior part and one in front of the spinnerets, RDTA with big blunt prong, MS tiny (Fig. 15A,B). . . . . *H. flinders*
   Carapace orange or brown, abdomen with more than one pair of white dots or with chevrons. 10
10. Cymbium with retrobasal spine (Fig. 12A, 13A) . . . . . *H. aciculare*
    Cymbium without retrobasal spine (Fig. 14-19). . . . 11
11. Palpal tibia, DtiA EP anvil-shaped (Fig. 14A, 16A) . 12
    Palpal tibia, DtiA EP not anvil-shaped (Fig. 15A, 17-19) 13
12. EP with, inner edge semicircular, serrated; half way to IP with small spine (Fig. 14A). . . . . *H. driscolli*
    EP anvil-shaped, tip with internal spine. Spine and thorn in u-shaped position (Fig. 16A) . . . . . *H. marliesae*
13. Carapace orange, femora I-IV pale, slightly darker distally. Palp, RDTA with slender tip (Fig. 19A,B) . . . . . *H. quemuseum*
    Carapace medium or dark brown, legs clearly annulated, femora I-IV proximal part white, distal part dark brown 14
14. Abdomen with two pairs of white spots on top and one spot in front of the spinnerets. Palp, RDTA tip ventrally excavated (Fig. 19C,D) . . . . . *H. wamuseum*
    Abdomen with more than two pairs of white spots on top and more than one spot in front of the spinnerets. Palp, RDTA tip ventrally not excavated (Fig. 17A,B, 18A,B) 15
15. Palp, DTA long ellipsoid (Fig. 17A,B) . . . . . *H. perth*
    Palp, DTA semicircular (Fig. 18A,B) . . . . . *H. stirling*

KEY TO SPECIES OF DESCRIBED FEMALES OF *HOLASTERON*

1. Epigyne with two lateral sausage-, sickle-shaped or slit-like CO (Fig. 6, 7C,D, 9C,D, 10C,D) 2
   Epigyne, CO central, more or less semicircular (Fig. 11,12,14,16-18) 6
2. Abdomen with chevrons 3
   Abdomen with two pairs of white spots on top and one or two in front of the spinnerets 5
3. Epigyne, S long sausage-shaped (Fig. 7C,D) . . *H. hirsti*
   Epigyne, S small globular or helical (Fig. 6A,B, 10C,D) . 4
4. S small globular (Fig. 6A,B) . . . . . *H. kangaroo*
   S helical (Fig. 10C,D) . . . . . *H. reinholdae*
5. CO slit-like, CD coiled 3 times, axis straight (Fig. 9C,D) . . . . . *H. humphreysi*
   CD short, coiled 2 times, axis in v-shaped position (Fig. 6C,D) . . . . . *H. aspinosum*
6. Femora I dark brown, with lateral white spot, II-IV proximal part white, distal part dark brown 7
   Femora I-IV proximal part white, distal part brown . . 8
7. Epigyne, without sclerotised tubes, CD coiled 3-4 times, axis v-shaped (Fig. 14C,D). . . . . *H. driscolli*
   Epigyne, with u-shaped sclerotised tubes, CD coiled about 6 times, axis straight (Fig. 11C,D). . *H. spinosum*
8. Carapace longer than 2.70 mm, CD coiled about 12 times (Fig. 17C,D). . . . . *H. perth*
   Carapace shorter than 2.60 mm, CD coiled about or less than 9 times (Fig. 12C,D, 16C,D, 18C,D) 9
9. CO broad-oval, with u-shaped sclerotised tubes, CD coiled about 9 times (Fig.15 A,B) . . . . . *H. aciculare*
   CO broad-oval, without sclerotised tubes, CD coiled about 7 times (Fig. 16C,D, 18C,D). 10
10. CO inverted flask-shaped, (Fig. 16C,D) . . *H. marliesae*
    Ends of CO spiral-shaped (Fig. 18C,D) . . . . *H. stirling*

Holasteron apinosum-group

Holasteron aspinosum sp. nov.
(Figs 3A, 5C,D, 6C,D, 20)

ETYMOLOGY. Greek *a-*, without; Latin *spinosus* thorny; elongate spine-shaped membrane at the base of DTA in the male palp is absent.

MATERIAL. HOLOTYPE: Western Australia: ♂, Glenbourne farm, Spring Rd, S. of Gracetown (site 1),

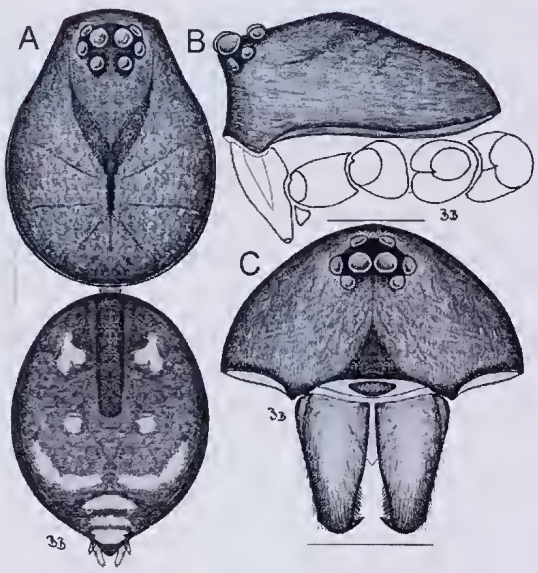

FIG. 2. *Holasteron perth*. A, body dorsal, B,C, carapace; B, lateral; C, frontal. Scale 1mm.

33°54'S, 115°00'E, 29-31 Mar. 1997, L. M. Marsh et al., dry pitfall (WAM T44601). PARATYPES: Western Australia: 34♂,3♀, Glenbourne farm, Spring Rd., S of Gracetown, site 4-6, 33°53'S, 115°00'E, 19-31 Mar. 1997, L.M. Marsh et al., dry pitfall (WAM T44602-5); 1♂,1♀, same data (QM S63008); 33♂,3♀, Glenbourne farm, Spring Rd, S. of Gracetown (site 4-6), 33°54'S, 115°00'E, 18-20 Apr. 1998, L.M. Marsh et al., dry pitfall (WAM T44606-8); 1♂, Glenbourne Farm, S. of Gracetown, near pitline 5, 33°54'40''S, 115°00'34''E, 28 March 1997, J.M. Waldock, et al. (WAM T54532); 1♂, Ledge Point, Site 3, 35°01'S, 118°17'E, 20 Mar. 1985, W. Humphreys et.al. (WAM93/913); 1♂, Woodman Point, 32°08'S, 115°44'E, 1 Apr. 1980, W.A.I.T. Biology students (WAM 90/433).

DIAGNOSIS. Apparently the western sister species of *H. kangaroo*, but can be distinguished by the colour pattern of the abdomen with 2 pairs of white spots on top and 2 in front of the spinnerets and the distally bent tip and prong of RDTA in the male palp.

DESCRIPTION. *Male* (holotype). 2.96 long. Carapace 1.52 long; 1.28 wide; 0.72 high; cl/cw 1.18; sternum 0.72 long; 0.76 wide; sl/sw 0.94; abdomen 1.44 long; 1.00 wide. Clypeus 0.36 high.

Colour: Carapace sepia brown, pale spots along lateral margin; sternum, chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, dorsally with 2 pairs of white spots on top and 2 in front of the spinnerets; laterally with 2 elongate white patches; ventrally pale brown. Legs pale brown, clearly annulated, with darker brown lateral stripes; coxae, trochantera I-IV pale; femora I-IV proximal part white, distal part pale brown.

Eyes: AME largest, ALE smallest; eye group width 0.57 of head width; AME 0.12; ALE 0.09; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.26; PME-PME 0.26. Clypeus 0.36 high.

Male palp (Figs 3A, 5C,D): PE not reaching tibia; RDTA with distally bent prong; TBE broadened. VTiA short; DTiA IP tiny, EP strongly sclerotised with blunt flattened area distally.

Female (paratype). 3.76 long. Carapace 1.72 long; 1.20 wide; 0.72 high; cl/cw 1.43; sternum 0.76 long; 0.80 wide; sl/sw 0.95; abdomen 2.04 long; 1.52 wide.

Colour: As in males.

Eyes: AME largest, ALE smallest; eye group width 0.59 of head width; AME 0.12; ALE 0.09; PME 0.1; PLE 0.1; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.05; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.25; PME-PME 0.25.

Epigyne (Fig. 6C,D): With 2 lateral sickle-shaped CO, CD short, coiled 2 times, axis in v-shaped position, ending in basal circular S.

DISTRIBUTION. SW Western Australia (Fig. 20).

Holasteron hirsti sp. nov.
(Figs 3B, 7, 20)

ETYMOLOGY. For David Hirst, curator of the spider collection, South Australian Museum.

MATERIAL. HOLOTYPE: South Australia: ♂, Ngarkat Conservation Park, 35°40'S, 140°47'E, 20Apr-15May 1999, Archie J. McArthur, pitfall (SAM NN11908). PARATYPES: South Australia: 2♂, same data as holotype (SAM NN11909-10); 16♂, Aldinga Scrub, 35°17'S, 138°28'E, 25 Mar-13 Apr, 1987, E. Matthews, J. Forster, pitfall (SAM N1992541-56); 2♂, 1♀, Gairdner-Torrens Basin, Olympic Dam site Roxby Downs, 30°27'S, 136°53', Mar-Jun, 1987, A. Smith, pitfall (SAM N1992418-20); 4♂, 12♀, Franklin Islands, 32°27'S, 133°40'E, May 1985, B. Guerin, pitfall (SAM N1994400-15); 1♂, Hambridge Cons Park, 33°27'S, 135°56'E, Apr. 1984, B. Guerin, pitfall (SAM N1994416); 4♂, 1♀, Kangaroo Island, 1 km E Vivonne Bay, Kl Dunnart Survey, SD05, 35°58'S, 137°10'E, 1-7 Mar 1995, T. Herbert, pitfall, (SAM NN11919-23);1♀, Kangaroo Island, 6km SW Vivonne Bay, 35°59'S, 137°10'E, 15-17 Nov. 1990, N.P.W.S. Survey (SAM N1992557); 3♂, 1♀, Kangaroo Island, Kiawarra, 1.7km SSE, 35°56'S, 137°17'E, 1-7 Mar. 1995, D. Herbert, Dunnart Survey Pitfall (SAM NN19915-18); 19♂,

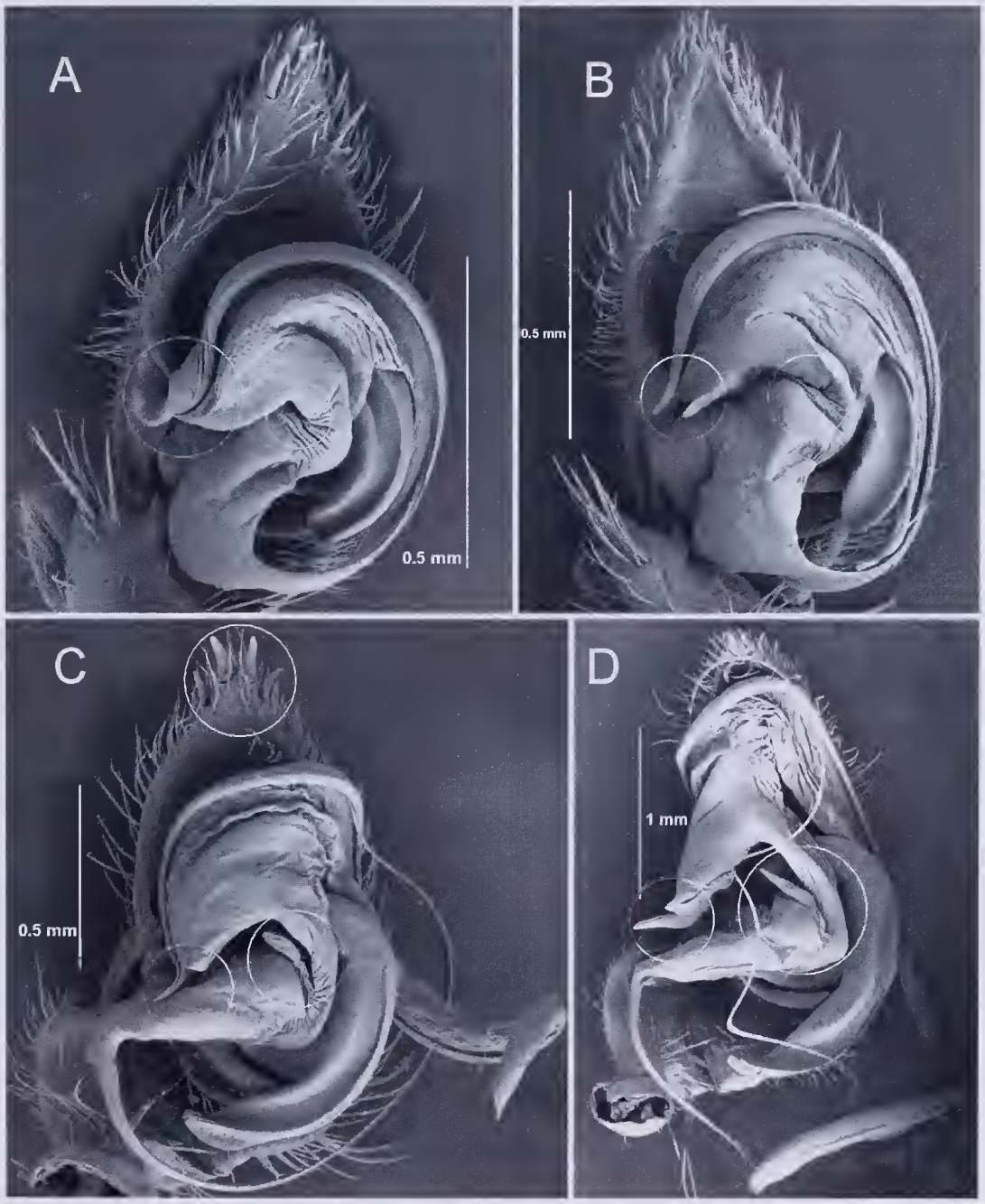

FIG. 3. *Holasteron* spp. right ♂ palps, ventral. A, *H. aspinosum*; B, *H. hirsti*; C, *H. spinosum*; D, *H. perth.*

Katarapko, Murray River NP, 34°24'S, 140°34'E, 24Apr.-1July 1991, A.J. McArthur, pitfall (SAM N1992454-72); 8♂ (SAM N199275-82); 9♂, 2♀, Keilira, 13km N, 36°35'S, 140°10'E Mar-Apr 1969, D. Hirst, pitfall (SAM N1994426-36); 4♂, Loxton 5km N, Berri 15km S, 34°24'S, 140°34'E, 1 July 1991, A.J. McArthur (SAM N199254-57); 6♂, Loxton, 20km S, 34°37'S, 140°36'E, 24Apr-31July 1991, A.J. McArthur, pitfall (SAM N1992483-88); 33♂, Loxton, 34°37'S, 140°25'E, 9 May 1991, A.J. McArthur pitfall (SAM N1992507-39); 14♂, 22.5km SW Loxton,

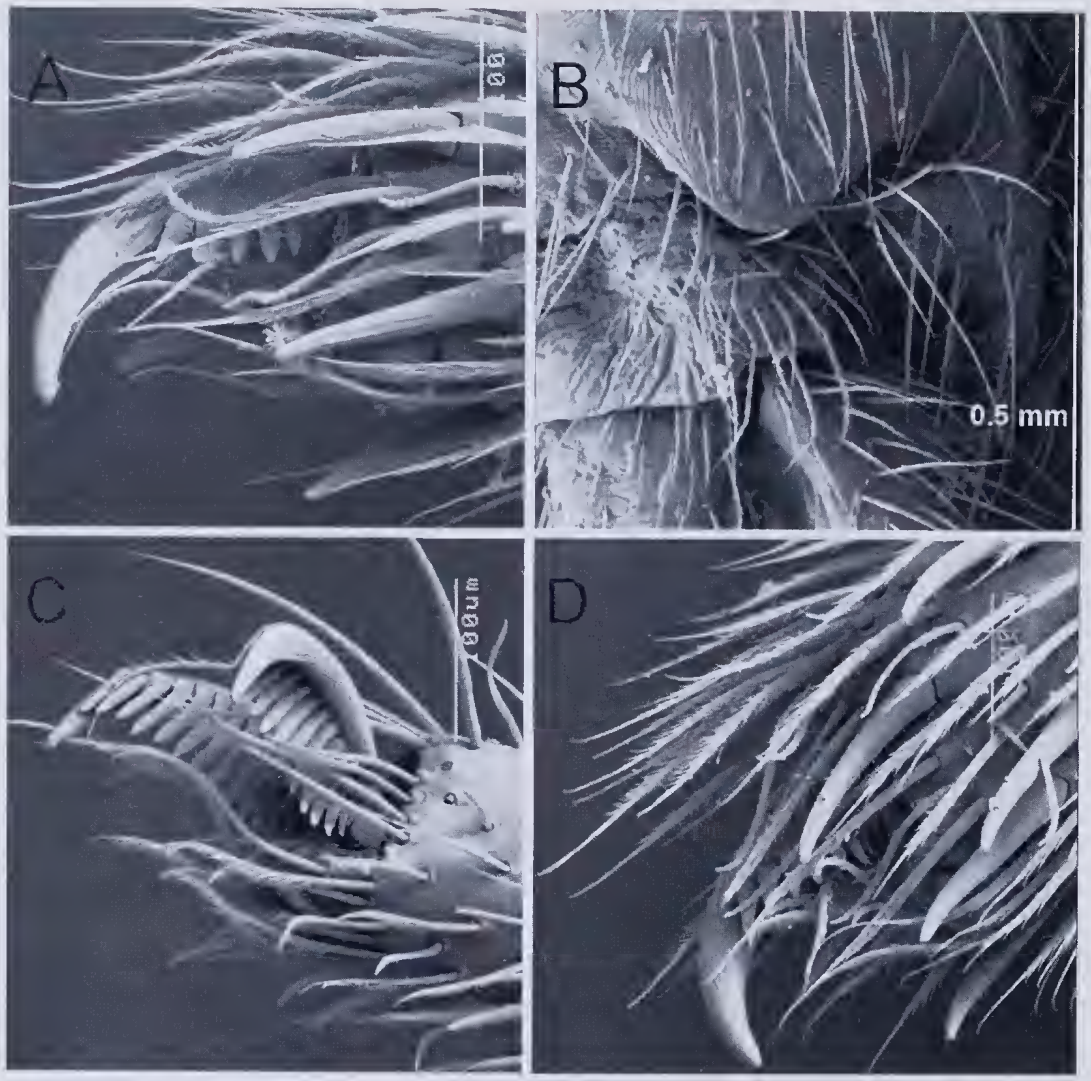

FIG. 4. *Holasteron* spp. A, *H. hirsti* ♀ right palpal claw; B-D, *H. perth*; B, tracheal spiracle; C, first right claw; D, ♀ right palpal claw.

34°37'S, 140°36'E, 28May 1991, A.J. McArthur, pitfall (SAM N1992492-505); 3♂, Munyaroo Cons Park, 33°20'S, 137°12'E, 28 Apr 1991, W. Head, L. Jansen (SAM N1992449-51); 1♂, Pyap, 1.75km SSE, 34°27'S, 140°30'E, 17-23 June 1991, L.N. Nicolson (SAM NN1992453); 7♂, Renmark, 34°07'S, 140°37'E, 2 May-7 June 1995, K. Pullen, pitfall (QM S25271); 1♂, Yorke Peninsula, Ardrossan, towards Tiddy Widdy Beach 34°25'S, 137°55'E, 4 Apr 2002, D. Hirst (SAM NN19419); 1♂, Whyalla, 90km S, 33°51'S, 137°35'E, 8 May 1980, B.Y.Main (WAM T54608).

DIAGNOSIS. Apparently the southern sister species of the *H. aspinosum*-group, which it resembles in having a sclerotised, blunt, distally flattened EP of DTiA and a broadened TBE at the base of the embolus in males and 2 lateral sickle-shaped CO. Males can be distinguished by the tripartite RDTA with sharp tip and bilobate prong, females by the long sausage-shaped S.

DESCRIPTION. *Male* (holotype). 3.28 long. Carapace 1.68 long; 1.36 wide; 0.80 high; cl/cw 1.24; sternum 0.84 long; 0.80 wide; sl/sw 1.05; abdomen 1.60 long; 1.12 wide. Clypeus 0.4 high.

Colour: Carapace brown with pale spots along lateral margin; sternum, chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, with pale chevrons. Legs pale brown, annulated; coxae, trochantera

I-IV pale; pale; femora I-IV proximal part white, distal part pale brown.

Eyes: AME largest; eye group width 0.62 of head width; AME 0.14; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.30; AME-AME 0.30; PME-PME 0.28. Clypeus 0.40 high.

Male palp (Figs 3B, 7A,B): PE not reaching tibia; RDTA tripartite with sharp tip and bilobate prong; TBE broadened. VTiA short; DTiA IP tiny, EP strongly sclerotised with blunt flattened area distally.

Female (paratype). 4.04 long. Carapace 2.04 long; 1.36 wide; 0.88 high; cl/cw 1.50; sternum 0.92 long; 0.92 wide; sl/sw 1.00; abdomen 2.00 long; 1.20 wide.

Colour: As in male.

Eyes: Eye group width 0.66 of head width; AME 0.14; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.34; AME-AME 0.30; PME-PME 0.28.

Epigyne (Fig. 7C,D): With 2 small lateral sickle-shaped CO, CD short coiled 2 times in v-shaped position, ending in long sausage-shaped S.

REMARKS. There are quite pale specimens with pale carapace and with only darker cephalic and dorsal area.

DISTRIBUTION. Southern Australia (Fig. 20).

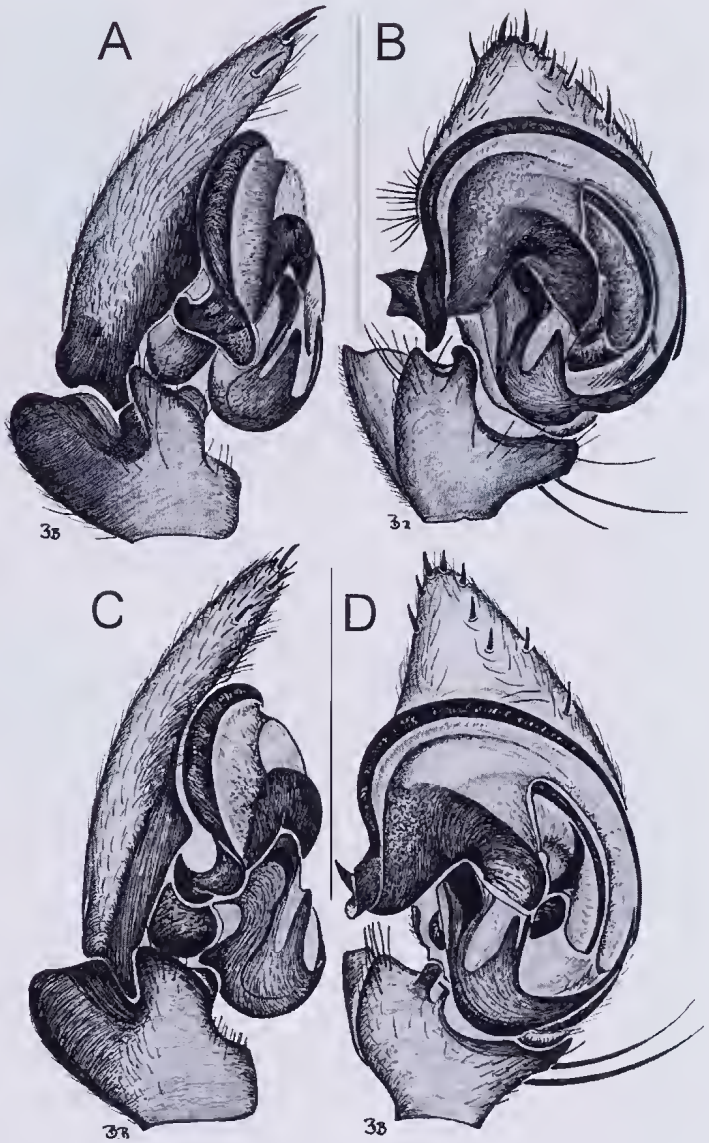

FIG. 5. *Holasteron* spp. right ♂ palps; A,C, retrolateral; B,D, ventral; A,B, *H. kangaroo;* C,D, *H. aspinosum*. Scale 0.5 mm.

Holasteron kangaroo sp. nov.
(Figs 5A,B, 6A,B, 20)

ETYMOLOGY. A noun in apposition with the type locality, Kangaroo Island.

MATERIAL. HOLOTYPE: South Australia: ♂, Kl Dunnart Survey, Kangaroo Island, 3.4 km E Woodlana, 35°38'30"S, 137°22'13"E, 17-23Mar 1995, T. Herbert, pitfall (SAM NN11911). PARATYPES: South Australia: 4♂, as for holotype (SAM NN11912-13), 1♂ same data (QM S63009); 1♀, Kangaroo Island, Dudley Conservation Park, 11.xi.1987, D. Hirst (SAM N1992560); 1♀, same data but 12.xi.1987 (SAM N1992559).

DIAGNOSIS. Apparently the southern sister species of *H. aspinosum*, but can be distinguished by the colour pattern of the abdomen with pale chevrons dorsally and the RDTA with basally directed tip and distally bent prong.

DESCRIPTION. *Male* (holotype). 2.84 long. Carapace 1.48 long; 1.20 wide; 0.68 high; cl/cw 1.23; sternum 0.72 long; 0.72 wide; sl/sw 1.00;

abdomen 1.36 long; 1.00 wide. Clypeus 0.28 high.

Colour: Carapace sepia brown with pale spots along lateral margin; sternum pale brown; chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, with pale chevrons. Legs pale brown, clearly annulated; coxae, trochantera I-IV pale; femora I-IV proximal part white, distal part pale brown; tibia I-IV proximal and distal part with brown spot.

Eyes: AME largest, ALE smallest; eye group width 0.65 of head width; AME 0.11; ALE 0.06; PME 0.09; PLE 0.09; AME-AME 0.02; AME-ALE 0.02; PME-PME 0.06; PME-PLE 0.10; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.24; PME-PME 0.24.

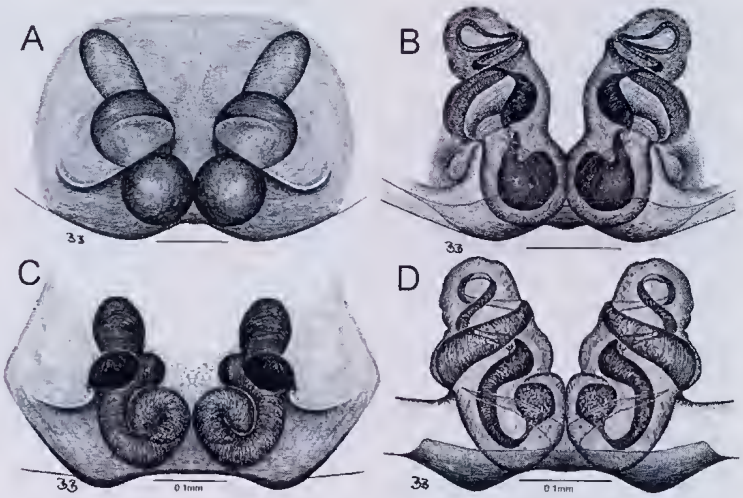

FIG. 6. *Holasteron* spp. epigyne; A,C, ventral; B,D, dorsal (cleared). A,B, *H. kangaroo*, C,D, *H. aspinosum*. Scale 0.1mm.

Male palp (Fig. 5A,B): PE not reaching tibia; RDTA with basally directed tip and distally bent prong; TBE broadened. VTiA short, triangular; DTiA IP tiny, EP strongly sclerotised with blunt flattened distal area.

Female (paratype). 4.20 long. Carapace 1.76 long; 1.28 wide; 0.80 high; cl/cw 1.23; sternum 0.84 long; 0.8 wide; sl/sw 1.05; abdomen 2.44 long; 1.8 wide. Clypeus 0.32 high.

Colour: As in male.

Eyes: eye group width 0.62 of head width; AME 0.12; ALE 0.08; PME 0.10; PLE 0.10; AME-AME 0.01; AME-ALE 0.01; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.26; PME-PME 0.26.

Epigyne (Fig. 6A,B): With two lateral, widely sickle-shaped CO, CD short, coiled 2 times, axis in v-shaped position, ending in small, non contiguous S.

DISTRIBUTION. South Australia, Kangaroo Island (Fig. 20).

Holasteron spinosum-group

Holasteron esperance sp. nov.
(Figs 8C,D, 21B)

ETYMOLOGY. A noun in apposition with the type locality.

MATERIAL. HOLOTYPE: Western Australia: ♂, Esperance Aboriginal Reserve (Part), 33°51'S, 121°51'E, 9 Nov. 1984, D. Mead-Hunter (WAM 90/244).

DIAGNOSIS. Apparently the southern sister species of *H. humphreysi*, which it resembles in having a short MS in male palps, but can be distinguished by the clearly annulated legs.

DESCRIPTION. *Male* (holotype). 3.36 long. Carapace 1.76 long; 1.44 wide; 0.80 high; cl/cw 1.22; sternum 0.80 long; 0.80 wide; sl/sw 1,00; abdomen 1.60 long; 1.12 wide. Clypeus 0.36 high.

Colour: Carapace, sternum, chelicerae orange; maxillae and labium yellow, distally white. Abdomen sepia brown, dorsally with two pairs of white spots on top and one spot in front of the spinnerets; laterally with one white patch. Legs pale brown, clearly annulated; coxae, trochantera I-IV pale; femora I-IV proximal part white, distal part pale brown; tibia I-IV proximal and distal part brown, medial part white.

Eyes: Nearly equal sized, AME largest; eye group width 0.57 of head width; AME 0.11; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.04; PME-PLE 0.10; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.24; PME-PME 0.24.

Male palp (Fig. 8C,D): Cymbium with 4 strong spines apically; short MS, PE reaching tibia; RDTA with sharp tip and well developed prong. VTiA short, with rounded tip; DTiA IP absent, EP as long as VTiA, with saddle.

Female unknown.

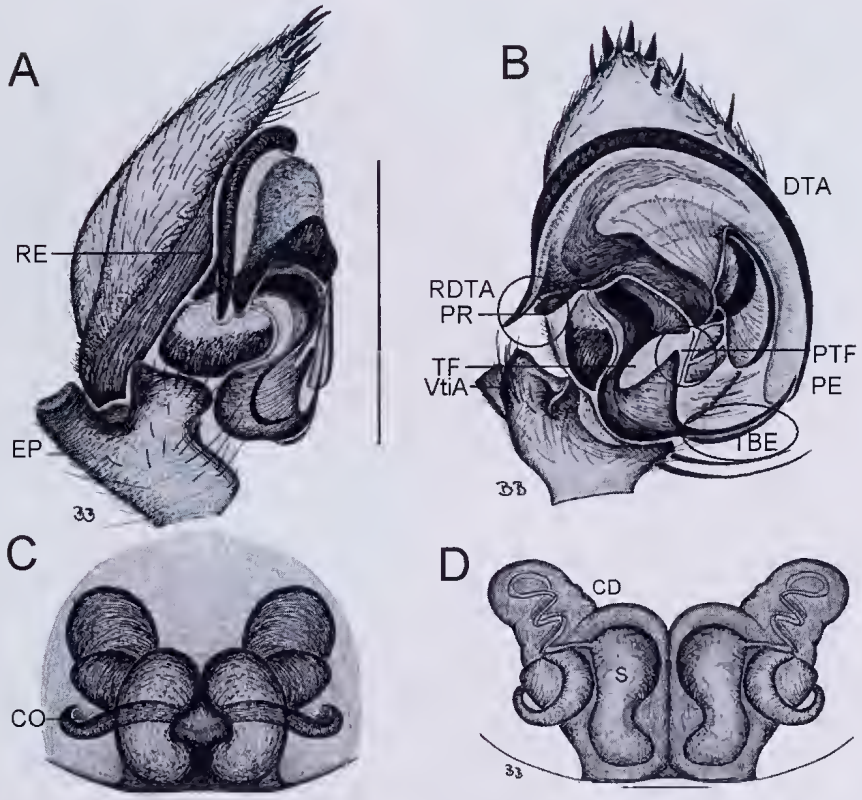

FIG. 7. *Holasteron hirsti*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne, C, ventral; D, dorsal; CO = copulatory opening; CD = copulatory duct; DTA = dorsal tegular apophysis; E = embolus; EP = external prong on dorso-retrolateral tibial apophysis (DtiA); PE = prolateral extension of DTA; PR = prong as ventral part of RDTA; PTF = prolateral transparent field on embolus base; RDTA = retrolateral extension of DTA; RE = retrolateral extension on cymbial flange; S = spermatheca; SP = sperm duct; TBE = transbasal area of embolus; TF = transparent field on embolus base; VtiA = ventral tibial apophysis; Scale 0.5 mm, 0.1mm.

DISTRIBUTION. S Western Australia, known only from type locality (Fig. 21B).

Holasteron humphreysi sp. nov.
(Figs 9, 21A)

ETYMOLOGY. For Bill Humphreys, Western Australian Museum, one of the collectors of the types.

MATERIAL. HOLOTYPE: Western Australia: ♂, Leeman Swamp, 26°37'S, 121°18'E, 29 Aug. 1982, R.P. McMillan (WAM 90/300). PARATYPES: Western Australia: 1♀ allotype, Nanga Station, Carnarvon Survey, 26°33'S, 113°58'E, 11 May-30 Aug. 1995, N. Hall, pitfall (WAM T53373); 2♂, Nanga Station, Carnarvon Survey, 26°33'S, 113°58'E, 11 May-30 Aug. 1995, N. Hall, pitfall (WAM T44525), 1♂, Nanga Station, 26°35'S, 113°53'E, 11 May-30 Aug. 1995, N.Hall, pitfall (WAM T44472); 2♂, Leeman Swamp, 26°37'S, 121°18'E, 29 Aug. 1982, R.P. McMillan (WAM T53372); 5♂, Edel Land, 26°32'S, 113°32'E, 5 May-30 Aug. 1995, N. Hall, pitfall (WAM T44478-9, T44524); 1♂, same data (QM S63006); 3♂, Boorabin, Goldfield Surveys, 31°13'S, 120°13'E, Mar. 1981, W.F. Humphreys et al., pitfall (WAM 90/66-67, 93/887); 1♂, Goongarrie, Goldfield Surveys, 29°54'S, 121°10'E, July 1981, W.F. Humphreys et al., pitfall (WAM 90/150); 3♂, Francois Peron N.P. 25°49'14''S, 113°32'24''E, 24 May-30Aug. 1995, N. Hall pitfall (WAM T54424).

DIAGNOSIS. Apparent northwestern sister species of *H. esperance*, which it resembles in having a short MS in male palps, but can be distinguished by the pale legs without any colour pattern. Females can be distinguished by the epigyne with two lateral sausage-shaped CO, CD short, 3 times coiled, axis straight.

DESCRIPTION. *Male* (holotype). 3.48 long. Carapace 1.72 long; 1.36 wide; 0.84 high; cl/cw 1.26; sternum 0.84 long; 0.84 wide; sl/sw 1.00; abdomen 1.76 long; 1.36 wide. Clypeus 0.32 high.

Colour: Carapace, chelicerae orange. Sternum yellow; maxillae and labium yellow, distally white. Abdomen sepia brown, dorsally with 2 pairs of white spots on top and 1 spot in front of spinnerets; laterally with 1 big white patch and pale booklungs. Legs pale brown.

Eyes: AME largest; eye group width 0.63 of head width; AME 0.12; ALE 0.08; PME 0.08; PLE 0.08; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.10; PME-PLE 0.09; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.26; PME-PME 0.26.

Male palp (Fig. 9A,B): Cymbium with 4 strong, apical spines; short MS; PE reaching tibia; RDTA with sharp tip only; VTiA short rounded; DTiA IP reduced to tiny knob, EP as long as VTiA, with saddle.

Female (paratype). 3.56 long. Carapace 1.72 long; 1.28 wide; 0.80 high; cl/cw 1.34; sternum 0.84 long; 0.80 wide; sl/sw 1.05; abdomen 1.84 long; 1.40 wide. Clypeus 0.32 high.

Colour: As in male but faded.

Eyes: Eye group width 0.60 of head width; AME 0.11; ALE 0.08; PME 0.08; PLE 0.08; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.26; PME-PME 0.24.

Epigyne (Fig. 9C,D): With two lateral sausage-shaped CO, CD short, 3 times coiled, axis straight, S helical and touching medially.

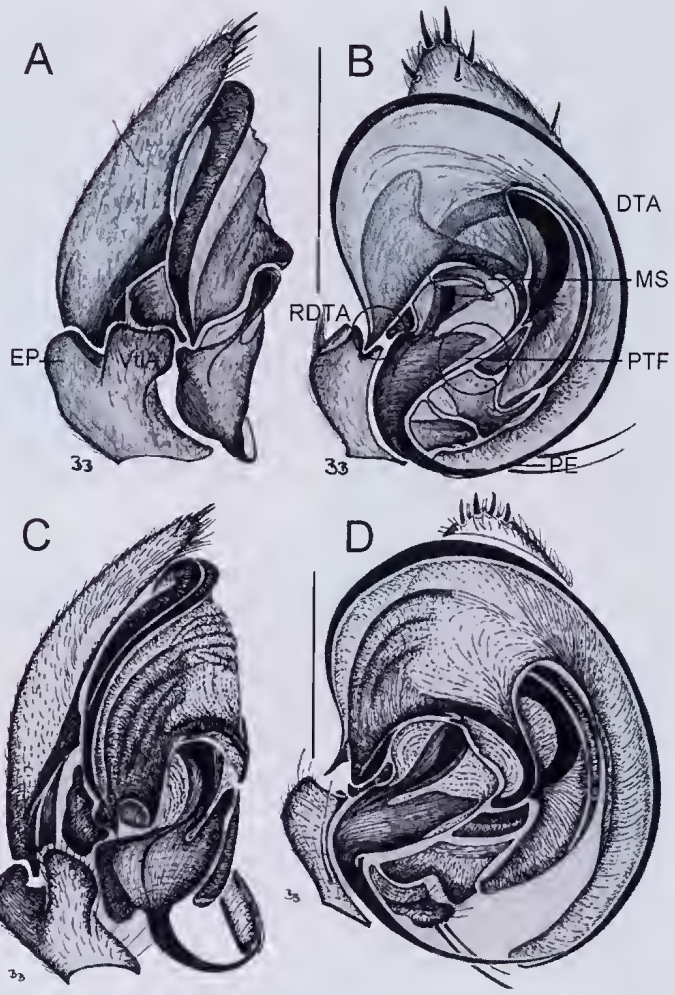

FIG. 8. *Holasteron* spp. right ♂ palps; A,C, retrolateral; B,D, ventral. A,B, *H. pusillum;* C,D, *H. esperance.* Scale 0.5 mm.

REMARKS. The female is in poor condition, hence the colour pattern is faded.

DISTRIBUTION. SW Western Australia (Fig. 21A).

Holasteron pusillum sp. nov.
(Figs 8A,B, 21B)

ETYMOLOGY. Latin *pusillum,* tiny.

MATERIAL. HOLOTYPE: South Australia: ♂, Poochera, Mudges, Heritage site, Nothomyrmecia search, 32°43'S, 134°50'E, 29 Oct.-7 Nov. 1995, A.J. Mcarthur (SAM NN11925). PARATYPES: Western Australia: 1m, Cave Entrance, Cocklebiddy Cave, 9 km S, under rock in doline, 32°00'S, 125°54'E, 3 Jan. 1972, M. Gray (AM KS15620).

DIAGNOSIS. Smallest of the *H. spinosum*-group and can be easily recognised by the eye size with ALE smallest, all other eyes equal sized and by the RDTA with only a sharp tip and without any prong in the male palp.

DESCRIPTION. *Male* (holotype). 2.96 long. Carapace 1.44 long; 1.08 wide; 0.64 high; cl/cw 1.33; sternum 0.60 long; 0.60 wide; sl/sw 1,00; abdomen 1.52 long; 1.04 wide. Clypeus 0.28 high.

Colour: Carapace, sternum orange brown; chelicerae medium brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, dorsally with pale chevrons; laterally with 2 elongate white patches. Legs medium brown, annulled, with darker brown lateral

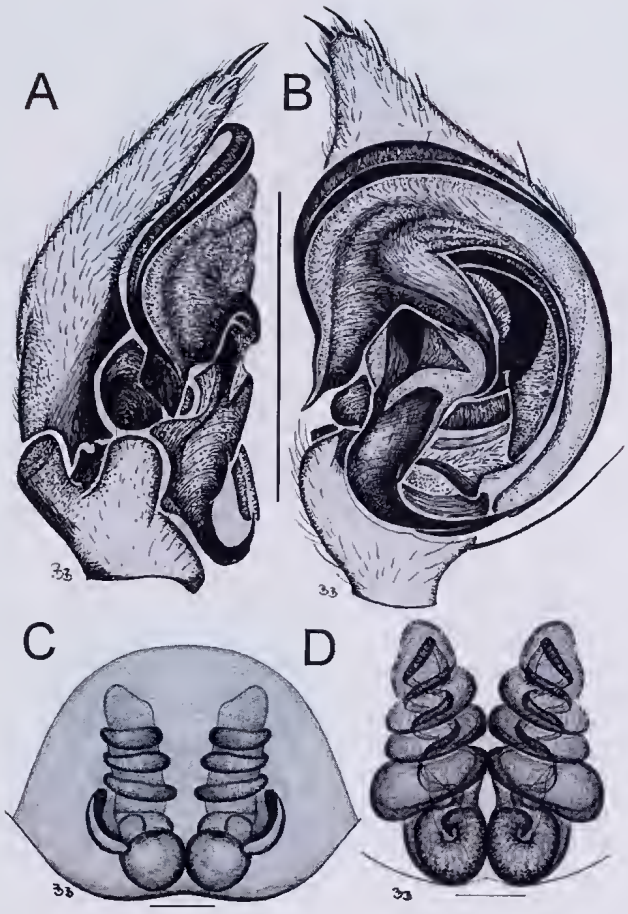

FIG. 9. *Holasteron humphreysi*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne, C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

stripes; coxae and trochantera I-IV pale; femora I dark brown, II-IV proximal part white, distal part dark brown; tibiae I-IV proximally pale, distally brown.

Eyes: nearly equal sized, ALE smallest; eye group width 0.62 of head width; AME 0.08; ALE 0.06; PME 0.08; PLE 0.08; AME-AME 0.02; AME-ALE 0.02; PME-PME 0.04; PME-PLE 0.06; ALE-PLE 0.02; eyes group AME-PME 0.22; AME-AME 0.18; PME-PME 0.20.

Male palp (Fig. 8A,B): Cymbium with 4 spines apically; elongate MS, at least 3 times as long as wide; PE reaching tibia; RDTA with sharp tip only; VTiA hooked; DTiA IP a tiny thorn, EP with blunt tip.

Female unknown.

DISTRIBUTION. Southern coastal Western Australia and South Australia (Fig. 21B).

Holasteron reinholdae sp. nov.
(Figs 10, 21B)

ETYMOLOGY. For Christa Deeleman (nee Reinhold).

MATERIAL. HOLOTYPE: Western Australia: ♂, Torndirrup Nat. Pk. 35°10'S, 117°50'E, 20-27 July 1983, P.H. Dyer, J. Lyon, 2yr burn, pitfall (WAM T53351). ALLOTYPE: Western Australia: 1♀, Torndirrup Nat. Pk. 35°10'S, 117°50'E, 22-29 June 1983, P.H. Dyer, J. Lyon, 2yr burn, pitfall (WAM T54531); PARATYPES: Western Australia: 8♂, Torndirrup Nat. Pk. 35°10'S, 117°50'E, 22-29 June 1983, P.H. Dyer, J. Lyon, 2yr burn (WAM T54658); 4♂, same data, 6-13 July 1983 2yr burn (WAM T54659); 14♂, same data , 13-20 July 2yr burn (WAM T54661); 16♂, same data , 20-27 July 2yr burn (WAM T54664); 4♂, same data , 13-20 July 17yr burn (WAM T54663); 12♂, same data , 13-20 July 4yr burn (WAM T54662); 1♂, same data , 6-13 July, 4yr burn (WAM T54660); 21♂, same data, 27 July-3 Aug. 1983, 2yr burn (WAM T53352); 17♂, same data, 4yr burn (WAM T54666); 2♂, same data, 20-27 July 1983, 17yr burn (WAM T54657); 1♂, same data, 17yr burn (QMS48697); 4♂, same data, 4yr burn (WAM T54665); 3♂, same data, 27 July-3 Aug. 1983, 17yr burn (WAM T54667); 1♀,6♂, Callcup Hill, Warren River area, 34°37'S, 115°53'E, 29 Oct.-7 Nov. 1997, C. Deeleman, pitfall (Leiden); 1♂, Callcup Hill, Warren River area, 34°37'S, 115°53'E, 29 Oct.-7 Nov. 1997, C. Deeleman, pitfall (QM S60980); 1♂, Callcup Hill, Warren River area, 34°37'S, 115°53'E, 29 Oct.-7 Nov. 1997, C. Deeleman, pitfall (Leiden).

DIAGNOSIS. Males resemble those of *H. spinosum* and *H. pusillum* in having the long MS, three times as long as wide but can be distinguished by the abdomen with pale chevrons, the RDTA with sharp tip and small flattened prong in males, the two small lateral u-shaped CO, and the short, 2 times coiled CD with axis in v-shaped position in females.

DESCRIPTION. *Male* (holotype). 3.28 long. Cephalothorax 1.68 long; 1.16 wide; 0.8 high; cl/cw 1.44; sternum 0.84 long; 0.84 wide; sl/sw 1; abdomen 1.6 long; 1.16 wide. Clypeus 0.32 high.

Colour: Carapace, chelicerae and sternum medium brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, with pale chevrons. Legs medium brown, annulated; coxae, trochantera I-IV pale; femora I-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.6 of head width; AME 0.1; ALE 0.08; PME 0.09; PLE 0.09; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.04; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.26; AME-AME 0.22; PME-PME 0.22.

Male palp (Fig. 10A,B): Cymbium 4 apical spines; elongate MS; PE reaching tibia; RDTA with sharp tip and small flattened prong; VTiA short, with incision; DTiA IP reduced to tiny knob, EP as long as VTiA, with saddle.

Female (paratype). 4.36 long. Cephalothorax 1.76 long; 1.24 wide; 0.8 high; cl/cw 1.41; sternum 0.84 long; 0.84 wide; sl/sw 1; abdomen 2.6 long; 2.12 wide. Clypeus 0.36 high

Colour: As in male.

Eyes: AME largest; eye group width 0.61 of head width; AME 0.12; ALE 0.1; PME 0.1; PLE 0.1; AME-AME 0.04; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.32; AME-AME 0.28; PME-PME 0.28.

Legs: Female palpal claw strong with 5 teeth.

Epigyne (Fig. 10C,D): With 2 small lateral u-shaped CO, CD short, 2 times coiled, axis in v-shaped position, S helical and touching medially.

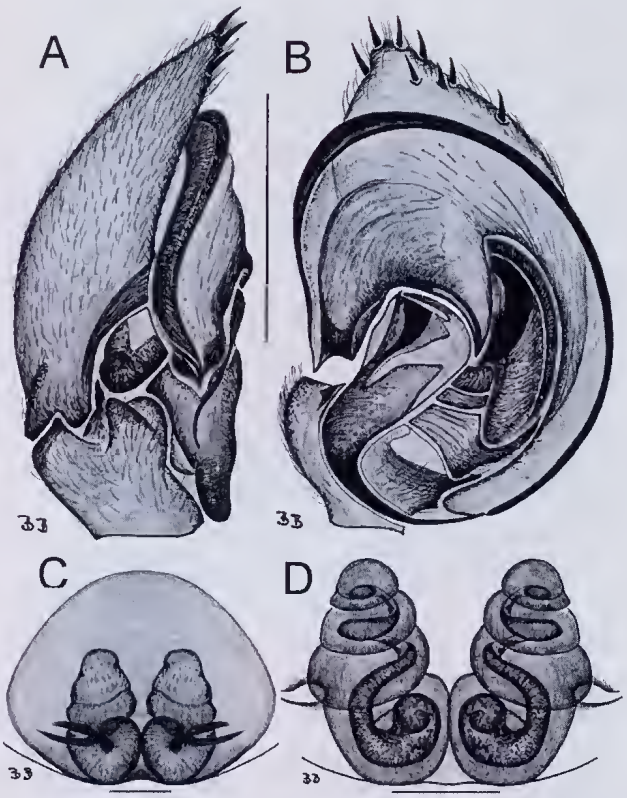

FIG. 10. *Holasteron reinholdae*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

REMARKS. The abdominal chevrons vary in size.

DISTRIBUTION. SW Western Australia (Fig. 21B).

Holasteron spinosum sp. nov.
(Figs 11, 21A)

ETYMOLOGY. Latin *spinosus,* spiny; refers to the well developed spine-shaped membrane (MS) at the base of DTA.

MATERIAL. HOLOTYPE: South Australia: ♂, Emu, 4.5km NW, 28°38'S, 132°10'E, 11 Oct. 1976, D.C. Lee (SAM N1992448). PARATYPES: South Australia: 1♂, Patawarta Bore, Narrina Stn., 1.3km N, 30°55'S, 138°43'E, 15-25 Mar. 1999,Flinders Ranges survey (SAM NN11938); 1♂, Arcoona Creek, Gammon Ranges, 30°26'S, 138°58'E, 2-6 May 1989, D. Hirst, J.A.Forrest (SAM NN11936); 1♂, Doongoonarra Waterhole, 6.6km SW, 28°16'S, 140°25'E, 14 Nov. 1994, R. Brandle, Stony Desert Survey, pitfall (SAM NN11956); 1♂, Hammat Dam, 1km E, 32°51'S, 139°32'E, 28 Oct. 1992, South Olary Plains Survey, pitfall (SAM NN11929); 1♂, Mt Coffin, 16km ESE Mooloolloo, 30°35'S, 138°40'E, 9-20 Dec. 1997, NW Flinders Ranges Survey, pitfall (SAM NN11935); 1♂,1♀, Renmark, Calperum Station, 34°00'S, 140°45'E, 28 Mar.-4 May 1995, K.R. Pullen (QM S50681); 4♂, Central Ranges, 31.5km ENE Mimili, 26°54'S, 133°00'E, 24-31 Oct. 1998, Pitjantjatjara Lands Survey, pitfall (SAM NN11365-8); 1♂, Central Ranges, 26.3km ENE Mimili, 26°55'S, 132°57'E, 25-31 Oct. 1998, Pitjantjatjara Lands Survey, pitfall (SAM NN11364); 1♂, Central Ranges, 19.9km WNW Indulkana, 26°54'S, 133°07'E, 25-31 Oct. 1998, Pitjantjatjara Lands Survey, pitfall (SAM NN11376); 1♂, Central Ranges, 9.4km SE Maryinna Hill, 27°01'S, 131°17'E, 14-18 Mar. 1995, Pitjantjatjara Lands Survey, pitfall (SAM NN11377); 1♂, Mt Coffin, 8.3km ESE Mooloolloo, 30°35'S, 138°35'E, 9-12 Dec. 1997, NW Flinders Ranges Survey, pitfall (SM NN11934); 4♂, 2♀, 29.7km WNW Indulkana, 26°52'S, 133°02'E, 24-31 Oct. 1998, Pitjantjatjara Lands Survey, pitfall (SAM NN11369-75). Victoria: 1♂, 17 km SW of Hattah, 34°51'S, 142°08'E, Oct. 1985, A.L. Yen, pitfall (VM). Western Australia: 1♂, Fraser Range Stn., 32°04'S, 122°48'E, 22 Apr. 1995, A.F. Longbottom (WAM T44420).

DIAGNOSIS. Largest of the *H. spinosum*-group can easily be recognised by the 4 strong spines at

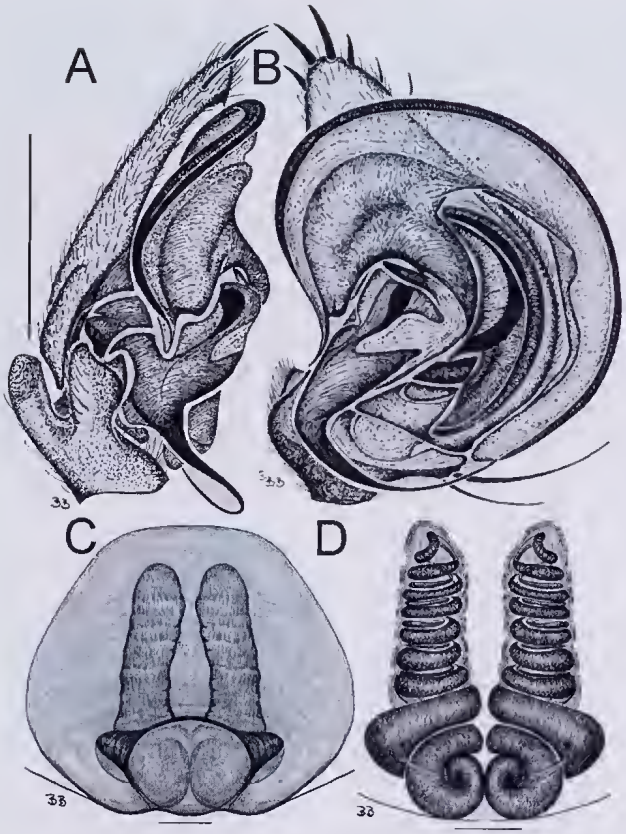

FIG. 11. *Holasteron spinosum*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

the end of the male palpal cymbium and the RDTA with sharp tip and small flattened prong. Females differ from other species of the *H. spinosum*-group by the broadly oval CO, with small u-shaped sclerotised tubes.

DESCRIPTION. *Male* (holotype). 4.00 long. Carapace 1.92 long; 1.44 wide; 0.72 high; cl/cw 1.33; sternum 0.84 long; 0.80 wide; sl/sw 1.05; abdomen 2.08 long; 1.56 wide. Clypeus 0.36 high.

Colour: Carapace; sternum; chelicerae sepia brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, dorsally with 2 pairs of white spots on top and 1 spot in front of the spinnerets; laterally with 2 elongate white patches. Legs medium brown, annulated, with darker brown lateral stripes; coxae and trochantera I-IV pale; femora I dark brown, with white patch laterally, II-IV proximal part white, distal part dark brown; tibiae I-IV proximally pale, distally brown.

Eyes: AME largest; eye group width 0.59 of head width; AME 0.12; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.04; ALE-PLE 0.08; eyes group AME-PME 0.3; AME-AME 0.26; PME-PME 0.26.

Male palp (Fig. 11A,B): Cymbium with 4 strong, apical spines; elongate MS; PE reaching tibia; RDTA with sharp tip and small flattened prong. VTiA with incision; DTiA IP reduced to tiny knob, EP as long as VTiA, with saddle.

Female (paratype). 6.64 long. Carapace 2.08 long; 1.52 wide; 0.84 high; cl/cw 1.34; sternum 1.00 long; 0.92 wide; sl/sw 1.08; abdomen 4.56 long; 2.28 wide. Clypeus 0.36 high.

Colour: As in male.

Eyes: AME largest; eye group width 0.55 of head width; AME 0.14; ALE 0.12; PME 0.12; PLE 0.12; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.04; ALE-PLE 0.08; eyes group AME-PME 0.34; AME-AME 0.30; PME-PME 0.30.

Epigyne (Fig. 10C,D): CO broadly oval, with small u-shaped sclerotised tubes, CD elongate, about 6 times coiled, axis straight. S helical and touching medially.

REMARKS. Abdomen of females can be twice of normal size when the female is carrying eggs as in the measured paratype.

DISTRIBUTION. S Western Australia, South Australia and north Victoria in open Acacia woodland. (Fig. 21A).

Holasteron aciculare-group

Holasteron aciculare sp. nov.
(Figs 12, 13, 22)

ETYMOLOGY. Latin *acicularis*, needlelike; refers to the long, needle-shaped tip of the RDTA.

MATERIAL. HOLOTYPE: South Australia: ♂, Pyap, 1.75km SSE, 34°27'S, 140°30'E, 11 July 1990, L.N. Nicolson, pitfall (SAM NN12000). PARATYPES: South Australia: 1♂, Pyap, 1.75km SSE, 34°27'S, 140°30', 17-23 June 1991, L.N. Nicolson, pitfall (SAM NN12001); 1♂, Adelaide, Daw Park, 34°59'S, 138°35'E, June 1971, N. Storey (SAM NN11990); 1♂, Adelaide, Paracombe, 34°51'S, 138°47'E, 19 Oct. 1988, G. Cooper (SAM N1992278); 1♂, Adelaide, Windsor Gardens, 34°56'S,

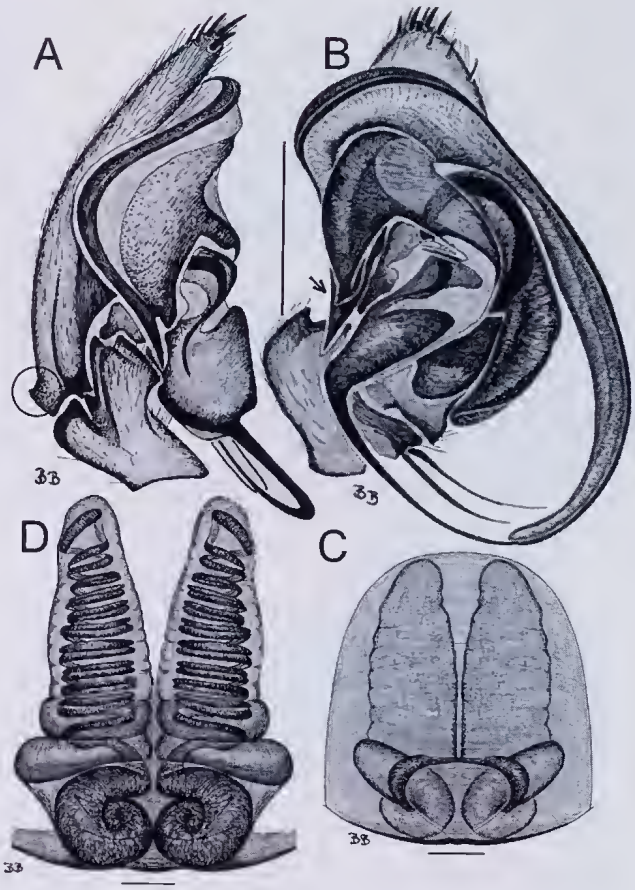

FIG. 12. *Holasteron aciculare*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

138°36'E, 24 May 1989, D. Hirst (SAM N199265); 1♂, Eyre Peninsula, Charlton Gully, 34°33'S, 135°47'E, Nov.- Dec. 1999, L. Bebbington (SAM NN11964); 1♂, Ferries Mcdonald National Park, 35°13'S, 139°09'E, 19 May 1977, E.G. Matthews (SAM N199270); 8♂, Hallet Cove, 35°05'S, 138°30'E, 25 Sep. 1994, A.J. McArthur, pitfall (SAM NN1191-8); 4♂, Loxton, 22km SW, 34°34'S, 140°22'E, 1 July 1991, A.J. McArthur (SAM NN12003-6); 1♀, Loxton, 20km S, 34°37'S, 140°36'E, 9 May 1991, A.J. McArthur, pitfall (SAM N199277); 12♂, Loxton, 20km S, 34°38'S, 140°36'E, Aug-Sept. 1991, A.J. McArthur, pitfall (SAM NN12007-19); 21♂, Loxton, 8.5km S, 34°37'S, 140°36'E, 1 July 1991, A.J. McArthur, pitfall (SAM NN12020-40); 7♂, Loxton, 5km N Katarapko, 34°24'S, 140°34'E, 1 July 1991, A.J. McArthur, pitfall (SAM NN12041-7); 1♂, Loxton, Katarapko, Murray River NP., 34°24'S, 140°34'E, Sep. 1991, A.J. McArthur, pitfall (SAM NN12002); 2♂, Loxton, 4km N, Murray River NP., 34°24'S, 140°34'E, 6 Aug.1991, A.J. Mcarthur, pitfall (SAM N1992274-5); 1♂, 1♀, Mt Lofty Ranges, Melville Gully, Belair, 35°02'S, 138°40'E, 25 Oct. 1992, A.J. McArthur, pitfall (SAM NN1982-3); 1♂, Mt Lofty Ranges, Coromandel Valley, 1km S, 35°02S, 138°38'E, 26 Oct. 1996, L.N. Nicolson (SAM NN11979); 2♂, Mt Lofty Ranges, 1km S Coromandel Valley, 35°02'S, 138°38'E, 18 Oct. 1984, L.N. Nicolson; (SAM NN11976-7); 1♂, Mt Lofty Ranges, Coromandel Valley, 35°02'S, 138°38'E, Dec. 1998, L.N. Nicolson (SAM NN11981); 1♂, Mt Lofty Ranges, Coromandel Valley, 0.8km SSW, 35°02'S, 138°38'E, 7 Dec. 1998, L.N. Nicolson (SAM NN19404); 1♂, Mt. Lofty Ranges, 1km S Coromandel Valley P.O., 35°02'S, 138°38'E, 6-20 Dec. 1993, L.N. Nicolson (SAM NN11978); 1♂, Mt Lofty Ranges, Coromandel Valley, 35°02'S, 138°38'E, 6-20 Dec. 1993, L.N. Nicolson (SAM NN11980); 1♂, Mt Lofty Range, Aldgate, 35°01'S, 138°44'E, Apr. 1969, A.W. Forbes (SAM N1992269); 1♂, Murray Bridge, 35°07'S, 139°16'E, 26 July 1998, M. Ludewigs (SAM NN11974); 1♂, Salisbury, 34°46'S, 138°39'E, A.J. McArthur, Nastec, pitfall (SAM NN11999); 2♂, Wild Horse Plains, 34°21'S, 138°18'E, 1- 27 June 1956, O.S. Martin (SAM N199272-3); New South Wales: 1♂, Glencoe, New South Wales, 29°56'S, 151°44'E, 29 Nov. 1962, E.S. Ross, D.Q. Cavagnaro, CAS; 1♂, Gilgurry State Forest, Rivertree Fire trail, on ridge approx 2km NNE from turnoff, 28°45'S, 152°15'E, 4 Feb-9 April 1993, M.Gray, G. Cassis, pitfall (AM KS36246); 1♂, Hazelbrook, end of Mount View Ave, 33°437'S, 150°28'E, 3 Oct. 1996, AMBS, pitfall (AM KS55662); 6♂, Narrabeen, Jamieson Park, 33°43'S, 151°18'E, 6-20 Nov. 1995, M. Gray, H. Smith, pitfall (AM KS44494, KS49064); 1♂, Ramornie State Forest, 150m, 29°43'S, 152°33'E, 4 Feb.-9 Apr. 1993, M.Gray, G. Cassis, pitfall (AM KS39450). Queensland: 1♂; Beerwah Forestry Reserve, 26°51'S, 152°57'E, 29 Aug. 1990, M. Glover, pitfall (QM S18368); 9♂, Consuelo Pk, 7.7km W, 1120m, 24°56'S, 148°05'E, 23 Aug.- 21 Jan. 2002, C. Eddie, pitfall (QM S58649); 1♂, Consuelo Pk, 3.5km W, 140m, 24°56'S, 148°08'E, 23 Aug.-21 Jan. 2002, C. Eddie (QM S58638); 1♂, Expedition Range NP., 'Amphitheatre' camp, 560m, 25°12'S, 148°59'E, 25 Sep.-18 Dec. 1997, G. Monteith, intercept trap (QM S44448); 5♂, 9♀, Lake Broadwater, via Dalby, 27°21'S, 151°06'E, 26 Jan. 1985- Jan. 1986, M. Bennie, pitfall (QM S47623-5, S47385, S35293); 2♂,5♀, Lake Broadwater, via Dalby, 27°21'S, 151°06'E, 2 Jan.- 25 Feb. 1986, M. Bennie, itfall (QM S15723); 9♂, Peawaddy Lkt., 2.6km W, 1120m, 24°55'S, 148°02'E, 24 Aug. 2001-21 Jan. 2002, C. Eddie, pitfall (QM S58651); 1♂ Texas, Pike Creek Dam Site, 23°05'S, 145°50'E, 9 Nov. 1973, R.J. McKay (QM S4388); 1♂, Woodford, 9.5km NEN, 26°56'S, 152°52'E, 24-25 Aug. 2002, D.J. Cook (QM S60809). Victoria: 1♂, Barmah forest, 35°56S, 145°03'E, Jan. 2001, A. Ballinger, pitfall (QM S60810); 1♂, Bendigo, Flora Hill, 36°47'S, 144°08'E, 9-16 May 2000, Ecology students (CVIC 825); 1♂, Eppalock Res. Redesdale, 36°51'S 144°23'E, 27 Nov. 1967, A. Neboiss (VM). Western Australia: 1♂, N. of Mt Dean, 33°13'56''S, 123°38'15E, 11 Apr. 2001, A. Baynes, leaf litter (WAM T44580), 1♂,

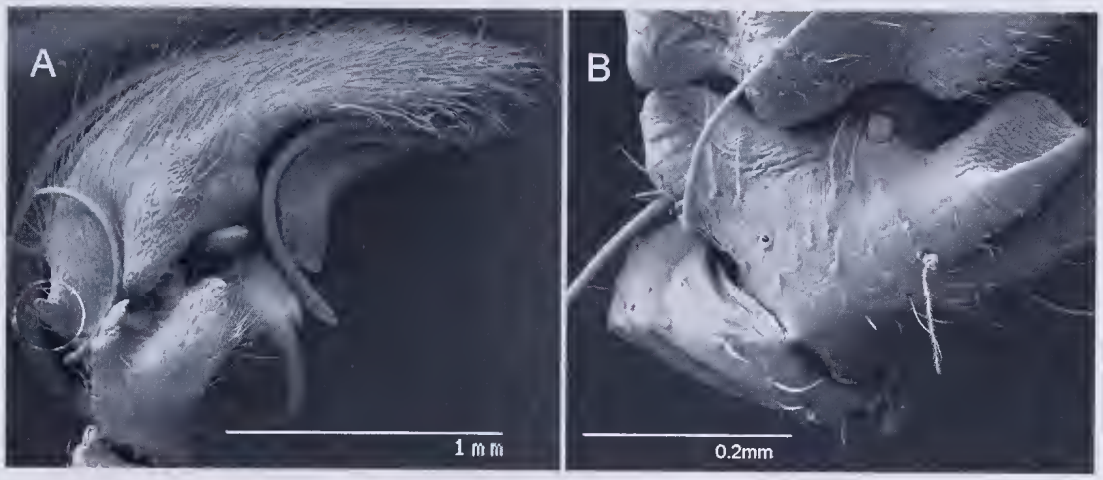

FIG. 13. *Holasteron aciculare*. A,B, right ♂ palp. A, retrolateral; B, dorsal view of tibia.

McDermid Rock, Goldfield Survey, 32°45'S, 120°02'E, 4 July 1979, R.A.How, pitfall (WAM 90/313); 2♂, Nullarbor Plain, 30°15'S, 127°43'E, Apr. 1930, C. Barrett (AM KS30355); 14♂, 3♀, Exclamation Lake, site SG 09B, 10B, 05B, 6A, 06B, 5A, 09A, 08A, 08B, 32°42'26''S, 121°29'31''E, 23-29 Apr. 2002, R. Teale et al. Dry pitfall (WAM T5432-40); 3♂, Nanambinia, 32°40'S, 123°35'E, 4-23 May 1986, B.Y. Main (WAM T54609).

DIAGNOSIS. This widespread species can be easily recognised by the cymbium with retrobasal spine in males and the female epigyne, with oval CO, u-shaped sclerotised tubes and elongate CD, coiled about 9 times.

DESCRIPTION. *Male* (holotype). 5.00 long. Carapace 2.60 long; 1.76 wide; 1.04 high; cl/cw 1.48; sternum 1.12 long; 0.92 wide; sl/sw 1.21; abdomen 2.40 long; 1.60 wide. Clypeus 0.48 high.

Colour: Carapace; sternum; chelicerae sepia brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, dorsally with or without weak scutum, with 2-3 pairs of white spots on top, the first and second can be elongated stripes, the third horizontal and 2-3 spots in front of the spinnerets; laterally with 2 elongate white patches. Legs pale brown, annulated, with darker brown lateral stripes; coxae I-IV pale; trochantera I-IV brown; femora I-IV proximal part white, distal part pale brown.

Eyes: AME largest; eye group width 0.52 of head width; AME 0.14; ALE 0.12; PME 0.12; PLE 0.12; AME-AME 0.04; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.34; AME-AME 0.32; PME-PME 0.32.

Male palp (Figs 12A,B, 13A,B): Cymbium with retrobasal spine (circle), elongate MS, PE longer than cymbium and tibia; RDTA with sharp tip and strong prong, from ventral view, prong overlapping tip. That is the case is all species of the *H. acilulare*-group and will be not mentioned in the descriptions of the other species. VTiA straight, with incision; DTiA IP a small spine, EP about half as long as VTiA, with distal saddle (Fig. 13B).

Female (paratype). 4.80 long. Carapace 2.60 long; 1.80 wide; 1.16 high; cl/cw 1.44; sternum 1.20 long; 1.04 wide; sl/sw 1.07; abdomen 2.20 long; 1.80 wide. Clypeus 0.52 high.

Colour: Carapace orange brown. Sternum orange, pale brown; chelicerae orange; maxillae and labium pale brown, distally white. Abdomen sepia brown, with 2 pairs of white spots on top and 2 in front of the spinnerets; laterally with chevrons; ventrally pale brown. Legs pale brown, annulated; coxae I-IV pale; trochantera I-IV pale, or brown; femora I-IV proximal part white, distal part pale brown.

Eyes: AME largest; eye group width 0.51 of head width; AME 0.16; ALE 0.14; PME 0.14; PLE 0.14; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.10; ALE-PLE 0.04; eyes group AME-PME 0.40; AME-AME 0.34; PME-PME 0.34.

Epigyne (Fig. 12C,D): CO oval, with u-shaped sclerotised tubes, CD elongate, about 9 times coiled, axis straight. S helical and touching medially.

REMARKS: This wide spread species varies in body length from 3.8-5.00, in colour of carapace

and abdomen from orange brown to deep sepia brown, in the abdominal colour pattern from 2 pairs of white dots on top and 1 in front of the spinnerets to 3 pairs on top and 2 in front of the spinnerets, with small or strong retrobasal spine. DTiA Ep with saddle undivided or divided. Examples here mentioned are from WAM 90/313, QM S47624 Lake Broadwater, QM S4388 Texas, HT SA NN12000.

DISTRIBUTION. S and W coastal region of Western Australia, S coastal region of South Australia, Victoria, E coastal region of New South Wales and SE Queensland (Fig. 22).

Holasteron driscolli sp. nov.
(Figs 14, 22)

ETYMOLOGY. For D. Driscoll, collector of the holotype.

MATERIAL. HOLOTYPE: New South Wales: ♂, Pullctop, 33°56'S, 146°06'E, 12-18 Oct. 1999, D. Driscoll, pitfall (QM S53275). PARATYPES: New South Wales: 1♂, Pullctop, 34°02'S, 146°04'E, 3-8 Nov. 1999, D. Driscoll, pitfall (QM S52827): 1♂, Pullctop, 33°59'S, 146°05'E, 12-18 Oct. 1999, D. Driscoll, pitfall (QM S53664); 2♂, Taleeban, 33°58'S, 146°27'E, 12-18 Oct. 1999, D. Driscoll, pitfall (QM S53035, S53180); South Australia: 2♂,1♀, Malinong, 35°31'S, 139°31'E, 21 Aug. 1999, J. Eckert, M. Ludewigs (SAM NN11971-73).

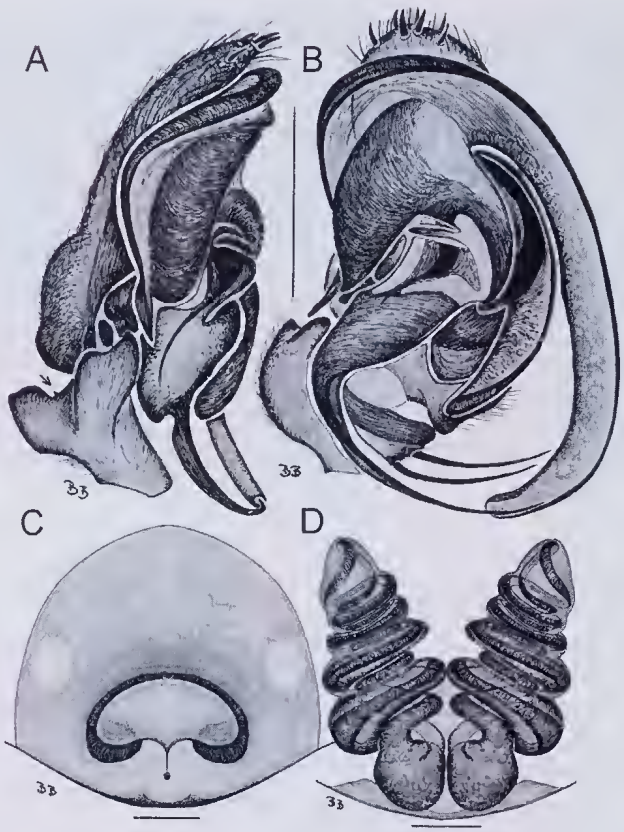

FIG. 14. *Holasteron driscolli*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

DIAGNOSIS. Resembling *H. marliesae* in shape of bulb and epigyne as well as in colour pattern but can be distinguished by DTiA, IP a tiny thorn, EP anvil-shaped, inner edge semicircular, serrated, half way to IP with small spine in males and in females with semicircular CO, without sclerotised tubes, with only 3 to 4 times coiled CD, axis in v-shaped position.

DESCRIPTION. *Male* (holotype).3.52 long. Carapace 1.80 long; 1.36 wide; 0.76 high; cl/cw 1.32; sternum 0.76 long; 0.76 wide; sl/sw 1.00; abdomen 1.72 long; 1.16 wide. Clypeus 0.32 high.

Colour: Carapace; sternum sepia brown; chelicerae medium brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, dorsally with weak scutum and 2 pairs of white spots on top and with 1 spot in front of the spinnerets or with pale chevrons; ventrally pale brown to dark brown. Legs pale brown, annulated, with darker brown lateral stripes; coxae and trochantera I-IV pale; femora I dark brown, with white patch laterally, II-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.58 of head width; AME 0.12; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.28; AME-AME 0.26; PME-PME 0.26.

Male palp (Fig. 14A,B): Cymbium with dorsal apical scopula and few strong spines, MS elongate, at least 3 times as long as wide; PE longer than cymbium and tibia. Tibia short, VTiA straight, with incision; DTiA IP a tiny thorn, EP anvil-shaped, inner edge semicircular, serrated, half way to IP with small spine.

REMARKS. The abdominal pattern can vary from 2 pairs of white dots on top and 1 spot in front of the spinnerets to pale chevrons.

Female (paratype). 4.36 long. Carapace 1.96 long; 1.32 wide; 0.84 high; cl/cw 1.48; sternum

0.86 long; 0.86 wide; sl/sw 1.00; abdomen 2.40 long; 1.48 wide. Clypeus 0.36 high.

Colour: As in male.

Eyes: AME largest; eye group width 0.58 of head width; AME 0.12; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.10; ALE-PLE 0.04; eyes group AME-PME 0.3; AME-AME 0.26; PME-PME 0.26.

Epigyne (Fig. 14C,D): CO semicircular, without sclerotised tubes, CD elongate, 3-4 times coiled, axis v-shaped, S touching medially.

DISTRIBUTION. SW New South Wales and SE South Australia (Fig. 22).

Holasteron flinders sp. nov.
(Figs 15, 23)

ETYMOLOGY. Noun in apposition with the type locality.

MATERIAL. HOLOTYPE: South Australia: ♂, Flinders Ranges National Park, 31°23'S 138°38'E, H.M. Hale (SAM N199263). PARATYPES: South Australia: 1♂, Aroona Valley, Northern Flinders Ranges, 31°18'S, 138°35'E, 13 Sep 1971, J. Forrest (SAM N1992264).

DIAGNOSIS. This biggest species of the *H. aciculare*-group can easily be recognised by the yellow carapace with dark cephalic area, by the abdominal pattern with 1 pair of white spots on posterior part and 2 in front of the spinnerets and by the structure of the male palp with very short MS.

DESCRIPTION. *Male* (holotype). Total length 6.08 long. Carapace 3.40 long; 2.36 wide; 1.28 high; cl/cw 1.44; sternum 1.48 long; 1.28 wide; sl/sw 1.15; abdomen 2.68 long; 2.08 wide. Clypeus 0.48 high.

Colour: Carapace yellow, with dark cephalic area; sternum yellow; chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, dorsally with weak scutum and 1 pair of white spots on posterior part and 1 spot in front of the spinnerets. Legs pale.

Eyes: AME largest; eye group width 0.50 of head width; AME 0.20; ALE 0.18; PME 0.18; PLE 0.18; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.14; ALE-PLE 0.04; eyes group AME-PME 0.50; AME-AME 0.50; PME-PME 0.42.

Male palp (Fig.15A,B): Tip of cymbium bent towards DTA; MS short, about 2 times as long as wide; PE longer than cymbium and tibia; VTiA long, straight, with incision; DtiA, IP reduced to tiny knob, EP about half as long as VTiA, with saddle.

Female unknown.

DISTRIBUTION. SE South Australia, known only from type locality (Fig. 23).

Holasteron marliesae sp. nov.
(Figs 16, 23)

ETYMOLOGY. For Marlies Kraenbring, who always supports me in my spirit .

MATERIAL. HOLOTYPE: New South Wales: ♂, Booti Booti NP, 32°15'S, 152°32'E, 9 Oct. 1997, L. Wilkie (AM KS84123). PARATYPES: New South Wales: 40♂,3♀, Booti Booti NP, 32°15'S, 152°32'E, 9 Oct. 1997, L.Wilkie (AM KS59538, KS59545-49, KS59553, KS55997, KS56081); 1♂ same data (QM S63007); 1♂, Booti Booti NP, 32°19'S, 152°31'E, 15 July 1996, L. Wilkie (AM KS50445); 1♂, Elsmore, 29°48'S, 148°17'E, 25 Aug. 1992, A.F. Longbottom (WAM 93/1156); 1♀, Munorah State Rec., 33°12'S, 151°35'E, 16 Dec. 1996, L. Wilkie (AM KS59537); 77♂,9♀, Munmorah State Rec. 33°12'S, 151°35'E, 11 Oct. 1997, L. Wilkie (AM KS59550-52, KS55945-46, KS55917-18, KS56041, KS59539-44).

DIAGNOSIS. This species resembles *H. driscolli* in shape of bulb and epigyne as well as in colour pattern but can be distinguished by DTiA

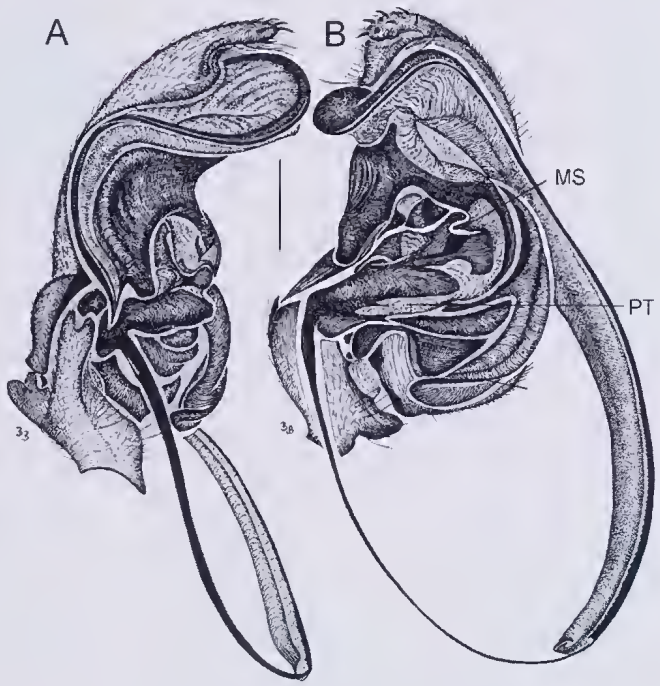

FIG. 15. *H. flinders*. A,B, right ♂ palp. A, retrolateral; B, ventral. Scale 0.5 mm.

bifurcate, VtiA, IP a tiny thorn, EP anvil-shaped, tip with internal spine. Spine and thorn in u-shaped position in males and in females with inverted flask-shaped CO, with sclerotised lip, CD about 7 times coiled and axis in straight position.

DESCRIPTION. *Male* (holotype). 3.52 long. Carapace 1.92 long; 1.44 wide; 0.88 high; cl/cw 1.33; sternum 0.88 long; 0.80 wide; sl/sw 1.10; abdomen 1.60 long; 1.12 wide. Clypeus 0.36 high.

Colour: Carapace orange brown. Sternum pale brown; chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, dorsally with weak scutum, 2-3 pairs of white spots on top and 1 spot in front of the spinnerets, laterally with chevrons. Legs medium brown, annulated, with darker brown lateral stripes: coxae and trochantera I-IV pale; femora I-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.55 of head width; AME 0.12; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.30; AME-AME 0.26; PME-PME 0.26.

Male palp (Fig. 16A,B): Cymbium with dorsal apical scopula and few strong spines; elongate MS, at least 3 times as long as wide; PE longer than cymbium and tibia; DTiA bifurcate, IP a tiny thorn, EP anvil-shaped, tip with internal spine. Spine and thorn in u-shaped position.

Female (paratype). 4.20 long. Carapace 1.92 long; 1.32 wide; 0.88 high; cl/cw 1.45; sternum 0.92 long; 0.84 wide; sl/sw 1.09; abdomen 2.28 long; 1.68 wide. Clypeus 0.36 high.

Colour: As in male.

Eyes: AME largest; eye group width 0.56 of head width; AME 0.11; ALE 0.10; PME 0.10; PLE 0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.32; AME-AME 0.24; PME-PME 0.26.

Epigyne (Fig. 16C,D): CO inverted flask-shaped, with sclerotised lip, CD elongate about 7 times coiled, axis in straight position, S touching.

DISTRIBUTION. N New South Wales (Fig. 23).

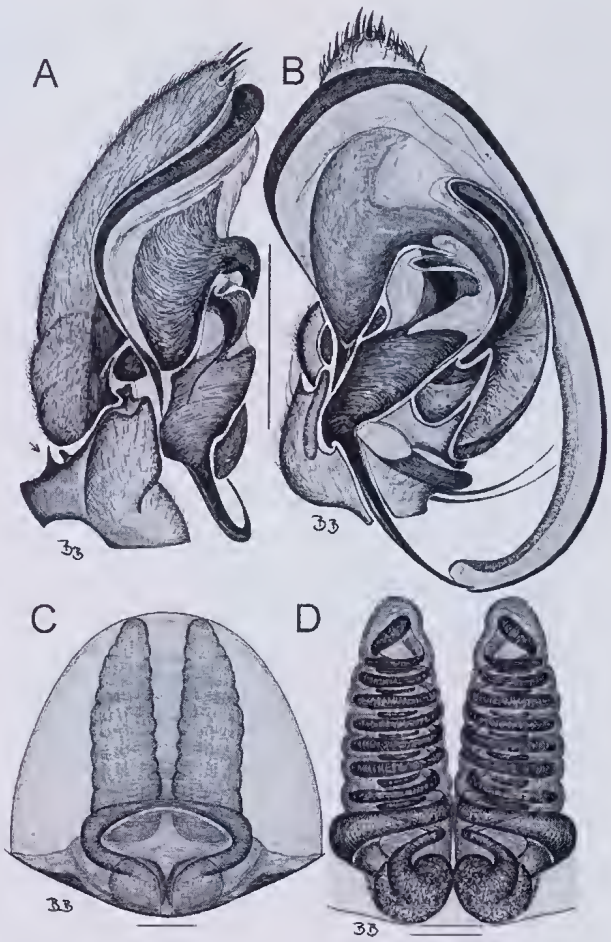

FIG. 16. *Holasteron marliesae*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scales 0.5mm, 0.1mm.

Holasteron perth sp. nov.
(Figs 2, 3D, 17, 22)

ETYMOLOGY. A noun in apposition with the type locality.

MATERIAL. HOLOTYPE: Western Australia: ♂, Talbot Road Reserve, site TR1, 31°52'S, 116°03'E, 18-31 Oct. 1993, J. Dell, pitfall dry (WAM 94/64). PARATYPES: Western Australia: 1♂,1♀, Talbot Road Reserve, site TR1, 31°52'05'S, 116°03'04"E, 24-29 Aug. 1993, J. Dell, pitfall dry (WAM95/357-58); 1♂,1♀, same data (QM S48700); 3♂, Talbot Road Reserve, site TR 1, 31°52'S, 116°03'E, 10-24 Oct. 1993, J. Dell, pitfall dry (WAM 94/63, 94/65-66), 1♂, Canning Well, 22°22'S, 121°18'E, July 1988, B. Harvey (MV K-3787); 1♂, Mundaring Summit Road, 31°54'S, 116°10'E, 13 Sept. 1994, A. Sampey, Photo D. Elford, film 9409-1 (WAM 94/1855); 1♂, Cape Arid, Thomas River, 34°01'S, 123°09'E, 18 Oct. 1988, C. Horseman (SAM KS29833); 1♂, Jerramungup, 34°02'S 118°55'E, Dec. 1983, G. Harold (WAM 95/319); 1♂, Perth

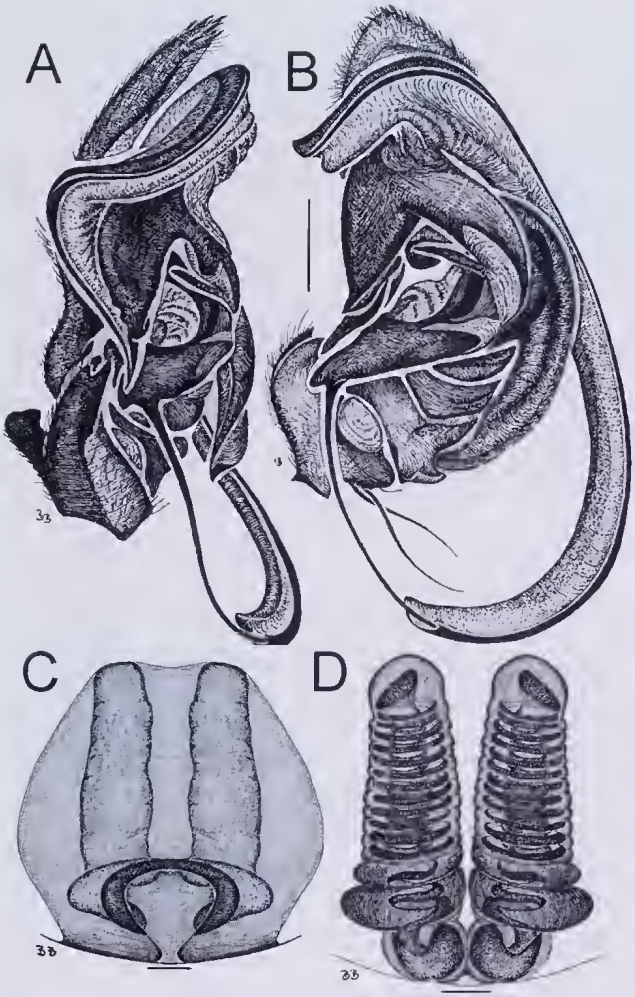

FIG. 17. *Holasteron perth.* A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5mm, 0.1mm.

Airport, site PA8, 31°59'S, 115°58'E, 24 Sep.-18 Nov. 1993, J.M. Waldock, pitfall (WAM 95/355); 1♂, Perth, Airport, site PA, 31°58'34''S, 115°58'25E, 28 July-23 Sep. 1993, J.M. Waldock, pitfall (WAM 94/52); 3♂, Perth Airport, site PA 6, 31°58'34''S, 115°58'25''E, 24 Sep.-18 Nov. 1993, J.M. Waldock, pitfall (WAM 95/352-54); 1♂, Perth Airport, site PA 7, 31°58'34''S, 115°58'25''E, 18 Nov.1993-7 Jan. 1994, J.M. Waldock, pitfall (WAM T54504); 2♂, Modong Nature Reserve, 32°14'S, 115°53'E, Oct.-Dec. 1997, B. Maryon et al., pitfall dry (WAM T44439).

DIAGNOSIS. Males resembles those of *H. flinders* in having the complex structure of the male palp but can be distinguished by the dark brown abdomen with 3 pairs of white spots on top and 2-3 spots in front of the spinnerets and in females by the inverted flask-shaped CO, by the horizontal directed u-shaped sclerotised tubes and by the extremely elongate CD, coiled about 12 times.

DESCRIPTION. *Male* (holotype). 5.40 long. Carapace 2.72 long; 2.20 wide; 1.40 high; cl/cw 1.23; sternum 1.24 long; 1.24 wide; sl/sw 1.00; abdomen 2.68 long; 1.92 wide. Clypeus 0.6 mm high.

Colour: Carapace orange brown; sternum pale brown; chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, dorsally with weak scutum, 2 pairs of white spots on top, one pair of moon-shaped spots behind and 2-3 spots in front of the spinnerets; laterally with 2 elongate white patches. Legs yellow, annulated, with darker brown lateral stripes; coxae and trochantera I-IV pale; femora I-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.55 of head width; AME 0.20; ALE 0.14; PME 0.14; PLE 0.14; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.10; PME-PLE 0.14; ALE-PLE 0.04; eyes group AME-PME 0.44; AME-AME 0.42; PME-PME 0.38.

Male palp (Fig. 3D, 17A,B): MS elongate, at least 3 times as long as wide; PE longer than cymbium and tibia. Tibia short; VTiA long, straight, with incision; DTiA bifurcate, lP a tiny thorn, EP with blunt tip.

Female (paratype). 6.96 long. Carapace 2.88 long; 2.00 wide; 1.40 high; cl/cw 1.44; sternum 1.20 long; 1.20 wide; sl/sw 1.00; abdomen 4.08 long; 2.88 wide. Clypeus 0.6 mm high.

Colour: As in male.

Eyes: AME largest; eye group width 0.53 of head width; AME 0.18; ALE 0.14; PME 0.14; PLE 0.14; AME-AME 0.04; AME-ALE 0.04; PME-PME 0.1; PME-PLE 0.14; ALE-PLE 0.06; eyes group AME-PME 0.46; AME-AME 0.4; PME-PME 0.38.

Epigyne (Fig. 17C,D): CO inverted flask-shaped, with u-shaped horizontally directed, sclerotised tubes, CD extremely elongate about 12 times coiled, axis in straight position, S touching.

VARIATION. The abdominal colour pattern can vary from 1-3 pairs of dorsal dots.

DISTRIBUTION. Western Australia (Fig. 22).

Holasteron quemuseum sp. nov.
(Figs 19A,B, 23)

ETYMOLOGY. For the Queensland Museum.

MATERIAL. HOLOTYPE: Queensland: ♂, Wycheproof, site 73 (2), tree clearing, brigalow, 23°38'S, 146°51'E, 1 July 1999, T. Churchill, pitfall (QM S60886). PARATYPES: Queensland: 1♂, Wycheproof, site 73 (2), 23°38'S, 146°51'E, 1 July 1999, D. Hannah, pitfall (QM S60887); 2♂, Lake Broadwater, 27°21'S, 15°o06'E, 22 Apr.-12 June 1986, M. Bennie, pitfall (QM S47383, S47384); 1♂, Oakpark, site 5(2), tree clearing, 26°04'S, 146°08'E, 26 Jan. 2000, D. Hannah, pitfall (QM S60885).

DIAGNOSIS. This species resembles *H. wamuseum* in shape of male palp but can be distinguished by the orange carapace and the abdominal colour pattern with pale chevrons.

DESCRIPTION. *Male* (holotype). 4.32 long. Carapace 2.28 long; 1.84 wide; 0.8 high; cl/cw 1.24; sternum 1.04 long; 1.04 wide; sl/sw 1.00; abdomen 2.04 long; 1.48 wide. Clypeus 0.52 high.

Colour: Carapace, sternum, chelicerae orange; maxillae and labium yellow, distally white. Abdomen medium brown; dorsally and laterally with pale chevrons; ventrally pale brown. Legs pale, with darker brown lateral stripes; coxae and trochantera I-IV pale; femora I-IV pale, slightly darker distally.

Eyes: AME largest; eye group width 0.60 of head width; AME 0.16; ALE 0.12; PME 0.12; PLE 0.12; AME-AME 0.02; AME-ALE 0.02; PME-PME 0.10; PME-PLE 0.10; ALE-PLE 0.02; eyes group AME-PME 0.36; AME-AME 0.34; PME-PME 0.34.

Male palp (Fig. 19A,B): Cymbium with few strong spines apically; MS elongate, at least 3 times as long as wide, PE longer than cymbium and tibia; VTiA hooked; DTiA bifurcate, IP a tiny thorn, EP slightly excavated.

Female unknown.

DISTRIBUTION. SE Queensland (Fig. 23).

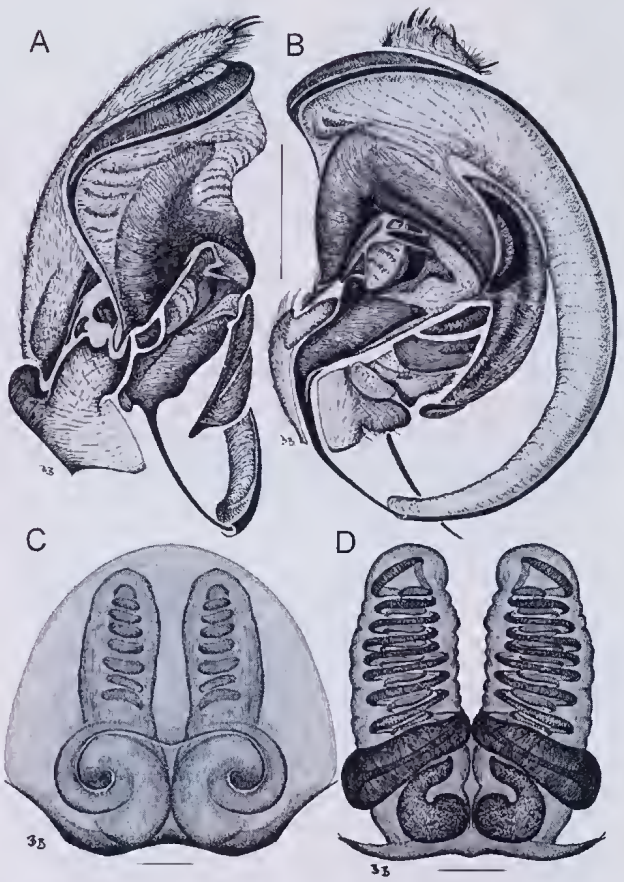

FIG. 18. *Holasteron stirling*. A,B, right ♂ palp. A, retrolateral; B, ventral; C,D, epigyne. C, ventral; D, dorsal. Scale 0.5 mm, 0.1mm.

Holasteron stirling sp. nov.
(Figs 18, 23)

ETYMOLOGY. A noun in apposition with the type locality.

MATERIAL. HOLOTYPE: Western Australia: ♂, Stirling Ranges NP, 12km S. Bluff Knoll, 34°29'S, 118°15'E, 23 Oct. 1989, G. Friend, G. Hall, D. Mitchell (WAM 93/886). PARATYPES: 1♂,1♀, Stirling Ranges NP., W. of Two Mile Lake, STR 1-1, 34°29'S, 118°15'E, 10-20 Sept. 1990, G. Friend pitfall (WAM T54451-2).

DIAGNOSIS. This species resembles *H. quemuseum* in shape of male palp but can be distinguished by the more semicircular DTA and the abdominal colour pattern with 3 pairs of white spots on top and 2-3 in front of the spinnerets.

DESCRIPTION. *Male* (holotype). 4.96 long. Carapace 2.64 long; 1.84 wide; 1.04 high; cl/cw 1.43; sternum 1.12 long; 1.08 wide; sl/sw 1.03; abdomen 2.32 long; 1.60 wide. Clypeus 0.8 high.

Colour: Carapace, sternum orange brown; chelicerae medium brown; maxillae and labium pale brown, distally white. Abdomen sepia brown, dorsally weak with scutum and 2-3 pairs of white spots on top and with 2-3 in front of the spinnerets, laterally with 1 big white patch and pale booklungs, ventrally pale brown. Legs pale, annulated; coxae and trochantera I-IV pale;

femora I-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.59 of head width; AME 0.16; ALE 0.12; PME 0.12; PLE 0.12; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.1; ALE-PLE 0.04; eyes group AME-PME 0.36; AME-AME 0.34; PME-PME 0.32.

Male palp (Fig. 18A,B): MS elongate, at least 3 times as long as wide; PE longer than cymbium and tibia. Tibia short; VTiA with incision; DTiA IP reduced to tiny knob, EP about half as long as VTiA, with saddle.

Female (paratype). 4.40 long. Carapace 2.12 long; 1.60 wide; 0.88 high; cl/cw 1.32; sternum 0.92 long; 0.92 wide; sl/sw 1.00; abdomen 2.28 long; 1.72 wide; clypeus 0.44 mm high.

Colour. As in male.

Eyes. AME largest; eye group width 0.56 of head width; AME 0.13; ALE 0.12; PME 0.12; PLE 0.12; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.04; PME-PLE 0.1; ALE-PLE 0.04; eyes group AME-PME 0.32; AME-AME 0.28; PME-PME 0.28.

Epigyne (Fig. 18C,D). With two spiral-shaped CO and sclerotised lip. CD elongate, coiled about 7 times, axis in straight position, S contiguous.

DISTRIBUTION. SW Western Australia. Known only from Stirling Ranges NP. (Fig. 23).

Holasteron wamuseum sp. nov.
(Figs 19C,D, 23)

ETYMOLOGY. For the Western Australian Museum.

MATERIAL. HOLOTYPE: Western Australia: ♂, Perth Airport, site PA7, 31°58'34"S, 115°58'25"E, 24 Jun-28July 1993, J.M. Waldock et al. (WAM T54503).

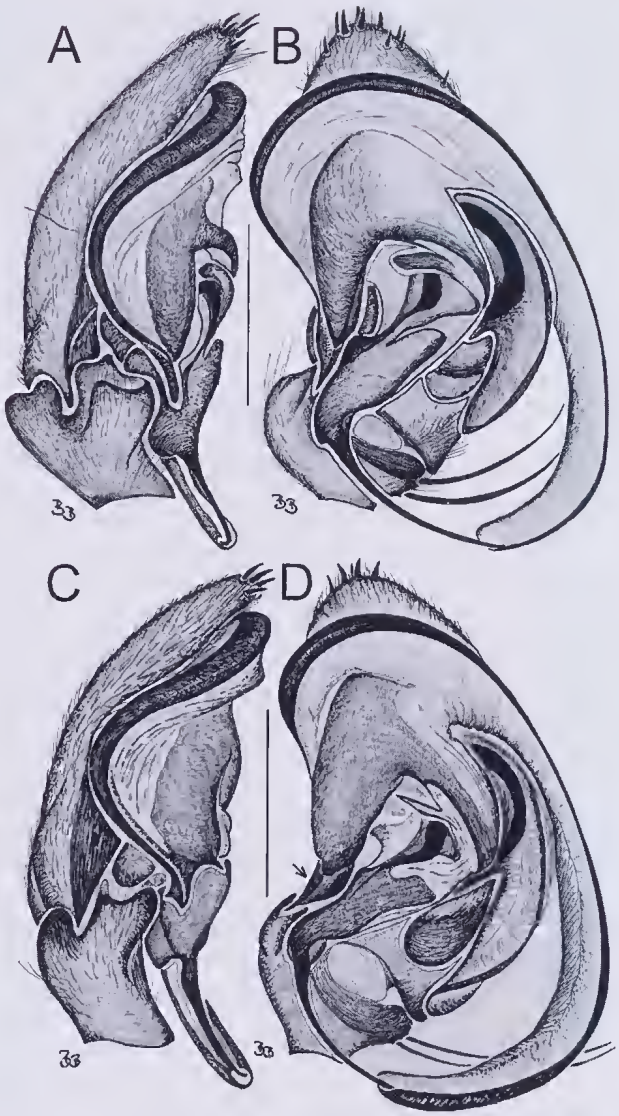

FIG. 19. *Holasteron* spp. right ♂ palps; A,C, retrolateral; B,D, ventral. A,B, *H. quemuseum;* C,D, *H. wamuseum.* Scale 0.5mm.

DIAGNOSIS. This species resembles *H. quemuseum* in shape of male palp but can be distinguished by the dark brown carapace, the abdominal colour pattern with 2 pairs of white spots and 1 spot in front of the spinnerets.

DESCRIPTION. *Male* (holotype). 3.48 long. Carapace 1.88 long; 1.36 wide; 0.96 high; cl/cw 1.38; sternum 0.84 long; 0.84 wide; sl/sw 1.00; abdomen 1.60 long; 1.20 wide. Clypeus 0.52 high.

Colour: Carapace and sternum sepia brown; chelicerae medium brown; maxillae and labium medium brown, distally white. Abdomen sepia brown, dorsally with 2 pairs of white spots on top and 1 in front of the spinnerets; laterally with 1 big white patch and pale booklungs. Legs pale brown, with darker brown lateral stripes; coxae and trochantera I-IV pale, femora I-IV proximal part white, distal part dark brown.

Eyes: AME largest; eye group width 0.52 of head width; AME 0.12; ALE 0.10; PME 0.10; PLE

0.10; AME-AME 0.02; AME-ALE 0.04; PME-PME 0.06; PME-PLE 0.08; ALE-PLE 0.04; eyes group AME-PME 0.30; AME-AME 0.26; PME-PME 0.26.

Male palp (Fig. 19C,D): Cymbium with few strong spines apically; elongate MS; PE longer than cymbium and tibia; RDTA consists of sharp tip with broad sail and strong prong. VTiA with incision; DTiA IP reduced to tiny knob, EP about half as long as VTiA, with saddle.

Female unknown.

DISTRIBUTION. Known only from Perth Airport (Fig. 23).

DISCUSSION

With this seventh systematic paper, the *Asteron*-complex (Baehr and Jocqué, 1996) now contains 13 genera with 112 species.

The 16 described species of *Holasteron* are medium-sized (2.8-7.00mm body length) and highly uniform in body shape, with broad oval carapace (Figs 1,2), maxillae without serrula, chelicerae without teeth, heart-shaped sternum and oval abdomen with a sclerotised tracheal spiracle (Fig. 4B) like all species of the *Asteron*-complex.

RECONSTRUCTED PHYLOGENETIC RELATIONSHIPS. The data matrix of 10 characters and 7 taxa (Tables 1, 2) was analysed with Hennig86 version 1.5 (commands: m*, bb**, tp display*) (Farris, 1988) and with NONA 2.0 (commands: amb- mult*1000) (Goloboff 1997). I analysed the data using unordered character states. Both programs generated the same single tree (length 15, consistency index 1.00 and retention index 1.00, Fig. 25). The cladogram of proposed relationships was created by hand with the same data using the original methods of Hennig (1966); this generated the same results (Fig. 25).

Basasteron leucoseum, *Euasteron enterprise* and *Spinasteron sanford* were selected as the outgroup taxa for comparison with the three species-groups of *Holasteron*.

I used only characters that I considered homologous and in which I was able to determine plesiomorphic and apomorphic character states. Based on these character states, I attempted to deduce the phylogenetic history of species-groups, detecting monophyletic clades (Hennig, 1966: Sudhaus & Rehfeld, 1992, p.137). Watrous & Wheeler's (1981) technique utilising outgroup comparion in phylogenetic analyses was taken to determine the polarity of the character states employed in this study.

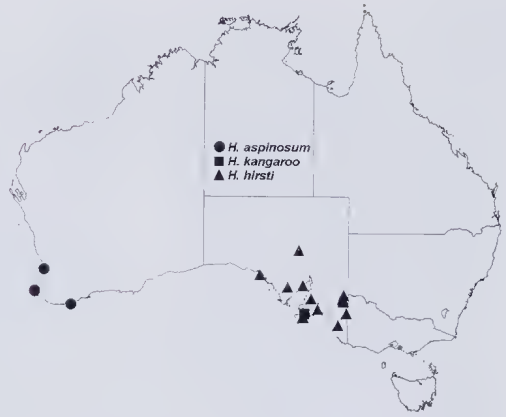

FIG. 20. Records of the *H. aspinosum*- and *H. hirsti*-group in Australia.

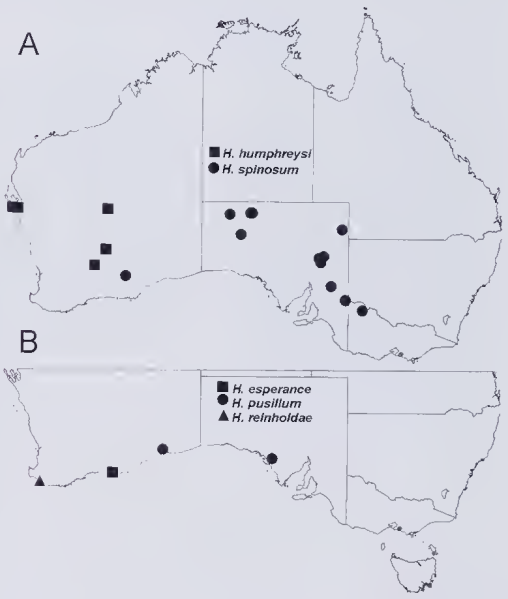

FIG. 21. Records of the *H. spinosum*-group in Australia.

Sometimes it is difficult to decide if characters or character states can be used as apomorphic characters, either because the direction of character development is doubtful or because it is unknown, whether and how many times the character states convergently evolved. Characters such as body shape or colour pattern, that are otherwise important for species identification are therefore difficult to use in the phylogenetic analysis.

In contrast to the genus *Tropasteron* where most of the species can be separated only with small differences in palpal characters and or in

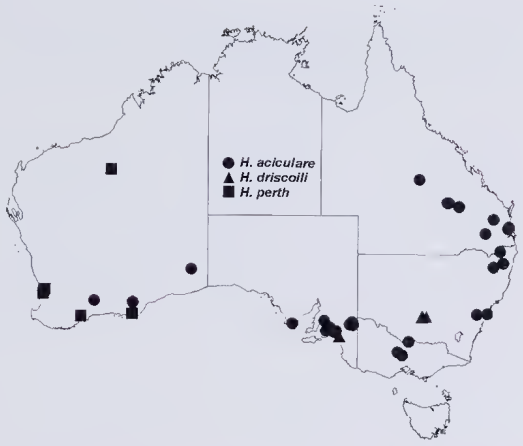

FIG. 22. Records of the *H. aciculare*-group in Australia.

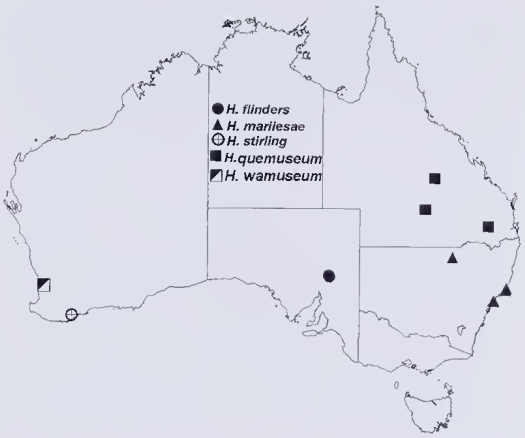

FIG. 23. Records of the *H. aciculare*-group in Australia.

abdominal colour pattern, in the genus *Holasteron* the differences are well defined and the palpal characters show increasing complexity.

The *Holasteron* species are characterised by their eye pattern with the eyes in 3 rows (2 4 2) and with AME always largest or at least equal to other eyes, in which they resemble the species of *Spinasteron*. The increase in size of the AME seems to be derived but happened presumably convergently at least three times in the *Asteron*-complex (some species of *Euasteron*, almost all species of *Spinasteron* and *Holasteron*). Nevertheless, as in most Australian zodariid genera (Baehr & Jocqué, 1996, 2000, 2001, Jocqué & Baehr, 2001), the definition of the genus *Holasteron* as a monophyletic unit, has been based on genitalic characters, especially of male palps (Fig. 25).

The main synapomorphies for the genus *Holasteron* are the flange with rounded extension, bent inside (2/*3*) and the additional prolateral transparent field (PTF) (4/*1*) at the base of the embolus. The 3 most plesiomorphic species without spine-shaped membrane and base of embolus not bent inside seem to be the *H. aspinosum*-group with the transbasal embolic area (TBE) flattened as its synapomorphy.

The *H. spinosum*- and *H. aciculare*-groups form a monophyletic unit supported by: (5/1) Base of embolus directed baso-laterad or retrolaterad, (6/1) base of embolus bent inside and 8/1 the presence of spine-shaped membrane at the base of DTA (MS).

The *H. spinosum*-group consists of 5 species and form the basal sister-group to *H. aciculare*-group with dorsoventral flattened palps and less number of coils of the copulatory duct (CD) in epigynes.

The 8 most derived species belong to the *H. aciculare*-group with a complex three-dimensional palp. As a consequence of that, the RDTA is folded behind the prong (9/*2*, Fig. 15A). The embolus is extremely long and accompanied by a long and ellipsoid prolateral extension of DTA (PE) (10/*4*) (Table 1). This increase of complexity happens in derived species of *Euasteron* and *Habronestes* as well and is well known as a normal phenomen in the evolution of spider palps Jocque & Baert (2002), mentioned in the revision of the genus *Tenedos*. The basal structure of the epigyne with coiled copulatory ducts, is similar to that of *Euasteron*, and *Spinasteron* species. But, as in male palps of the *H. aciculare*-group

FIG. 24. Records of the *Holasteron Spinasteron* and *Tropasteron* in Australia.

TABLE 1. Characters and character states of the *Holasteron* species-groups and their outgroups *Basasteron leucosemum* (Rainbow, 1920) and *Euasteron enterprise* (Baehr, 2003) and *Spinasteron sanford* (Baehr, 2003).

Male palp

0. Retrolateral cymbial flange small bump or extension (RE). ***0.*** absent. ***1.*** present.
1. Retrolateral cymbial flange (RE). ***0.*** rectangular. ***1.*** small bump ***2.*** with rounded extension. ***3.*** with rounded extension, bent inside.
2. Base of embolus prolaterad with flattened chitinous plate ***0.*** absent. ***1.*** present.
3. Base of embolus with additional prolateral transparent field (PTF). ***0.*** absent. ***1.*** present
4. Base of embolus. ***0.*** directed basally. ***1.*** directed baso-laterad or retrolaterad.
5. Base of embolus bent inside. ***0.*** absent. ***1.*** present.
6. Transbasal embolic area (TBE). ***0.*** thin cylindrical. ***1.*** flattened.
7. Spine-shaped membrane at the base of DTA (LTA) (MS). ***0.*** absent. ***1.*** present.
8. RDTA tip and membranous lamella (ML) or prong (PR) ***0.*** straight. ***1.*** distally bent prong. ***2.*** RDTA tip behind prong, from ventral view.
9. Prolateral extension (PE) length. ***0.*** Short about ¼ of circle. ***1.*** long about ½ of circle ***3.*** about ¾ of circle. ***4.*** extremely long ellipsoid.

All character states are unordered.

emboli became longer the copulatory duct (CD) increases in number of coils.

PHYLOGENY AND BIOGEOGRAPHY. Most zodariid species in Australia, especially of the *Asteron*-complex, are endemic to small areas, sometimes even only to a single rainforest block (e.g. *Tropasteron* Baehr, 2003b).

Holasteron includes 16 species that were found to belong to 3 species-groups. Whereas *Spinasteron* is restricted to NW Australia, *Holasteron* is distributed over SE, S and SW of Australia but is not recorded from the Northern Territory or NW Australia (Fig. 24).

1) The species of the most basal, *H. aspinosum-group*, are restricted to South Australia (*H. hirsti*, *H. kangaroo*) and SW Western Australia (Fig. 20).

2) The most basal species (*H. pusillum*) of the more derived *H. spinosum*-group is found only in South Australia and SE Western Australia. The other 4 species are distributed in South Australia and Victoria (*H. spinosum*) and SW Western Australia (*H. esperance*, *H. hirsti*, *H. reinholdae*) (Fig. 21).

TABLE 2. Character matrix for *B. leucosemum*, *E. enterprise*, *S. sanford* and all *Holasteron* species-groupgs.

	0-4	5-9
B. leucosemum	00000	00000
E. enterprise	12100	00000
S. sanford	11100	00000
H. aspin-gr. hirsti	13010	00000
H. aspin-gr. aspinosum	13010	00000
H. spinosum-group	13011	10103a
H. aciculare-group	13011	10124

3) The 8 most derived *Holasteron* species of the *H. aciculare*-group (*H. aciculare*, *H. driscolli*, *H. flinders*, *H. marliesae*, *H. perth*, *H. stirling*, *H. quemuseum* and *H. wamuseum*) have the widest distribution from S Queensland, to New South Wales, Victoria, South Australia and SW Western Australia (Figs 22, 23).

There is no evidence that the *Asteron*-group occurs outside Australia and each genus seems to be the result of independent radiations within the Australian continent.

The most basal species of the *Asteron*-complex (*Pentasteron simplex*, *Basasteron leucosemum* and *Euasteron enterprise*) are located in S Queensland and New South Wales. *Spinasteron* is, according to the phylogenetic analysis, a derived sister-genus of *Euasteron* (Baehr, 2003a). Species of *Euasteron* are found throughout Australia, species of *Spinasteron* are restricted to the faunal refugia of the Hammersleyan subregion in the most western part of Western Australia and of the Arnhemian and Kimberleyan subregions of Northern Australia mentioned in (Baehr, 1992), whereas *Holasteron* is distributed over SE, S and SW Australia.

The progressive complexity of the male palps within *Holasteron* follows a definite biogeographical pattern with South Australia in the centre, those species with a simple palp occur in South Australia and SW Western Australia, only. Those species with more complex palps have a much larger distribution occurring from Queensland to SW Australia (e.g. *H. aciculare*). This progressive complexity tracking biogeographic zonation from a centre to two directions (east-west), is not matched in other zodariid genera studied to date. For example, in *Tropasteron*, which is distributed throughout the rainforest pockets of E Queensland, no evolutionary pattern is evident and it was hypothesised that a series of small, parallel evolutionary changes occurred

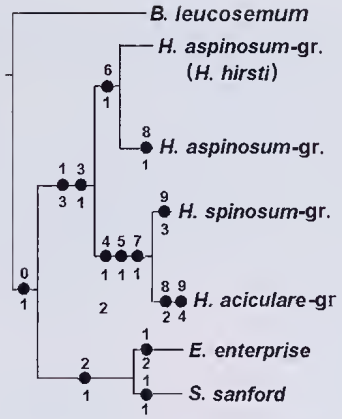

FIG. 25. Phylogeny of *Holasteron* species-groups, based on data set in Table 2. Cladogram of supposed relationships in sense of Hennig (1966), consistent with Hennig 86 and NONA (each of lengths 15, consistency index 1.00, retention index 1.00).

between the species along the entire length of the generic distribution (Baehr, 2003b).

ACKNOWLEDGEMENTS

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LITERATURE CITED

BAEHR, B. 2003a. Revisions of the new endemic genera *Basasteron*, *Euasteron* and *Spinasteron* of Australia (Araneae, Zodariidae): Three new genera of the *Asteron*-complex. Memoirs of the Queensland Museum 49(1): 1-27.

2003b. Revision of the tropical genus *Tropasteron* gen. nov. of North Queensland (Araneae, Zodariidae): a new genus of the *Asteron*-complex. Memoirs of the Queensland Museum 49(1): 29-64.

2003c. Revision of the Australian genus *Habronestes* L.Koch (1872) (Araneae: Zodariidae). The species of NSW. Records of the Australian Museum 55(3): 343-376.

BAEHR, B. & CHURCHILL, T. 2003. Revision of the endemic Australian genus Spinasteron (Aranea: Zodariidae): taxonomy, phylogeny and biogeography. Invertebrate Systematics 17: 641-665.

BAEHR, B. & JOCQUE, R. 1994. Phylogeny and zoogeography of the Australian genus *Storena* (Araneae, Zodariidae). Spixiana 17(1): 1-12.

1996. A revision of *Asteron*, starring male palpal morphology (Araneae, Zodariidae). Proceedings of the XIII International Congress of Arachnology, Geneva, 3-8 September 1995. Revue suisse Zoology, hors serie 1: 15-28.

2000. Revisions of the genera in the *Asteron*-complex (Araneae, Zodariidae). The new genera *Cavasteron* and *Minasteron*. Records of the Western Australian Museum 20: 1-30.

2001. Revisions of the genera in the *Asteron*-complex (Araneae, Zodariidae). The new genera *Pentasteron*, *Phenasteron*, *Leptasteron* and *Subasteron*. Memoirs of the Queensland Museum 46(2): 359-385.

CHURCHILL, T.B. 1998. Spiders as ecological indicators in the Australian tropics: family distribution patterns along rainfall and grazing gradients. Bulletin of the British Arachnological Society 11: 325-330.

DALLWITZ, M.J., PAINE, T.A. & ZURCHER, E.J. 1998. Interactive keys. Pp. 201-212. In Bridge, P., Jeffries, P., Morse, D.R. & Scott, P.R. (eds) 'Information Technology, Plant Pathology and Biodiversity'. (CAB International: Wallingford).

FARRIS, J.S. 1988. Hennig 86 Version 1.5 (Port Jefferson: New York).

GOLOBOFF, P.A. 1997. NONA version 2.0. (Department Entomology, American Museum of Natural History: New York).

HENNIG, W. 1966. Phylogenetic Systematics. (University of Illinois Press: Urbana).

JOCQUE, R., 1991. A generic revision of the spider family Zodariidae (Araneae). Bulletin of the American Museum of Natural History 201: 1-160.

JOCQUE, R. & BAEHR, B. 1992. A revision of the Australian spider genus *Storena* (Araneae, Zodariidae). Invertebrate Taxonomy 6: 53-1004.

2001. Revisions of the genera in the *Asteron*-complex (Araneae, Zodariidae): *Asteron* Jocqué and the New Genus *Pseudasteron*. Records of the Australian Museum 53: 21-36.

JOCQUE, R. & BAERT , L. 2002. A revision of the Neotropical spider genera *Tenedos* O.P. -Cambridge and Ishmia Chamberlin (Araneae, Zodariidae). Bulletin de L'Institut Royal des Sciences Naturelles de Belgique, Entomologie 72: 67-173.

RAINBOW, W.J. 1920. Arachnida from Lord Howe and Norfolk Islands. Records of the South Australian Museum 1: 229-272.

SUDHAUS, W. & REHFELD, K. 1992. Einfuehrung in die Phylogenetik und Systematik. Gustav Fischer Verlag. 1-241. Stuttgart, Jena, New York.

WATROUS, L.E. & WHEELER, Q.D. 1981. The out-group comparison method of character analysis. Systematic Zoology 30: 1-11.

SOUTHEASTERLY RANGE EXTENSION FOR *PROABLEPHARUS TENUIS* (SQUMATA: SCINCIDAE) IN QUEENSLAND. *Memoirs of the Queensland Museum 49(2): 520. 2004;-* Three species of *Proablepharus* are known from northern and western Australia. The genus is characterised by its small body size, short, pentadactyl limbs, and an immovable eyelid that is partially fused to form a permanent spectacle (Cogger, 2000). *Proablepharus tenuis* typically has a coppery-brown to olive-grey dorsal surface with a sprinkling of fine dark spots (Wilson & Swan, 2003).

This poorly known species is thought to occur in the sub-humid and semi-arid regions of Western Australia, Northern Territory and Queensland (WAM, 2003). In Queensland, Cogger (2000) described the range of *P. tenuis* as including most areas surrounding the Gulf of Carpentaria north to approximately Kowanyama and extending south to around Georgetown. Wilson & Swan (2003) described a similar distribution except that they showed the species continuing east to approximately Marceba and south almost to Aramac. This is similar to the range documented in the Western Australian Museum's database (FaunaBase), which contains a record of *P. tenuis* from the Aramac region (22°56'59"S, 145°40'59") (WAM, 2003).

The species is typically found under leaf-litter and fallen timber in dry selerophyll forests, and savannah woodlands with a spinifex understorey (Cogger, 2000; Wilson & Swan, 2003).

In 2001 and 2002 a systematic fauna survey was conducted at both Cudmore National Park and Nairana National Park respectively. Vertebrate fauna were surveyed using a combination of Elliott and pit fall traps, mist nets, harp traps, bat triplines, spotlighting, active searching and bird censuses over a period of 10 days at each location. A total of 165 vertebrate species were found during the survey at Cudmore National Park and 183 species were recorded at Nairana. Both surveys found several specimens of *P. tenuis*. The species was predominantly caught using pit fall traps at Cudmore National Park: 22°53'11"S, 146°16'51"E; 22°52'44"S, 146°19'47"E; 22°58'07"S, 146°22'52"E; and at 21°41'59"S, 146°55'36"E on Nairana National Park. The species was found in a range of different vegetation communities including tall eucalypt forests, open woodlands and heathlands with a spinifex understorey. These records represent a southeasterly range extension for the species. Six specimens were submitted to the Queensland Museum (QMJ 77062, QMJ76764, QMJ76758, QMJ76754, QMJ76744, and QMJ78747).

Acknowledgements

The following people are acknowledged for their assistance with fieldwork: John Clarke, Rhonda Melzer, Mark Fletcher, Greg Edmed, Joah Madden, Warren Williams, Vicki Crichton and Peta McGee To Rhonda Melzer for her comments on drafts. To the Queensland Museum for their assistance with specimen identification.

Literature Cited

COGGER, H.G. 2000. Reptiles and amphibians of Australia 6th Ed. (Reed New Holland: Sydney).

WESTERN AUSTRALIAN MUSEUM. 2003. FaunaBase (Database). Western Australian Museum. Perth.

WILSON, S. & SWAN G. 2003. A complete guide to reptiles of Australia. (Reed New Holland: Sydney).

John Augusteyn and Gary Porter, Queensland Parks and Wildlife Service, PO Box 3130, Rockhampton Shopping Fair 4701, Australia; 10 March 2004.

THE LARGE ASPIDORHYNCHID FISH, *RICHMONDICHTHYS SWEETI* (ETHERIDGE JNR AND SMITH WOODWARD, 1891) FROM ALBIAN MARINE DEPOSITS OF QUEENSLAND, AUSTRALIA

ALAN BARTHOLOMAI

Bartholomai, A. 2004 06 30: The large aspidorhynchid fish, *Richmondichthys sweeti* (Etheridge Jnr and Smith Woodward, 1891) from Albian marine deposits of Queensland, Australia. *Memoirs of the Queensland Museum* 49(2): 521-536. Brisbane. ISSN 0079-8835.

Material previously referred to the genera *Belonostomus* Agassiz, 1834, *Aspidorhynchus* Agassiz, 1833 and *Vinctifer* Jordan, 1919 from Lower Cretaceous (Albian) marine deposits of Queensland (Australia) is considered to be referable to *Richmondichthys* gen. nov., within the species *R. sweeti* (Etheridge Jnr & Smith Woodward, 1891). This is shown to be a very common and widespread aspidorynchid halecostome (Actinopterygii:Teleostei), the largest species within the family. *R. sweeti* differs significantly from the South American *V. comptoni* (Agassiz,1841), to which it is nonetheless closely related. Lack of teeth, elongate gill filaments, hinged cheek bones and a very deep lower jaw suggest the species was a filter feeder, possibly a gulper. ❑ *Actinopterygii, Halecostomi, Teleostei, Aspidorynchidae, Richmondichthys sweeti, Albian.*

Alan Bartholomai, Director Emeritus, Queensland Museum, PO Box 3300, South Brisbane 4101, Australia; *received 10 March 2004.*

Aspidorhynchid fish remains comprise conspicuous and common elements of the fossil vertebrates recovered from widespread localities in the Lower Cretaceous (Albian) marine deposits of the Great Artesian Basin in central Queensland. The majority of referred material from precisely recorded localities has been derived from the shallow water, marine sediments of the Toolebuc Formation, a unit rich in invertebrate fossils and containing not only fish but also a rich suite of marine and some terrestrial reptiles. Rarer aspidorhynchid occurrences are recorded from the Allaru Mudstone, also of Lower Cretaceous (Albian) age.

The presence of ganoid fish in the Great Artesian Basin deposits was first recorded by Etheridge (1872) in a collection of fossils from 'Hughenden Station' where they were referred to *Aspidorhynchus* sp. Jack & Etheridge (1892) later referred this material to *Belonostomus sweeti*, a species that had been described by Etheridge Jnr & Smith Woodward in 1891, also based on material from Hughenden in central Queensland.

The specimens then available lacked most of the cranial elements and the neurocranium remained undescribed. Over the past century, the available sample of remains referrable to the species has expanded considerably and acetic acid preparation techniques have permitted previously unheard of detail to be revealed from the encompassing concretionary, calcilutite structures in which the fossils are usually preserved. A much more comprehensive description of the taxon is now possible, enabling better comparisons with other genera and species.

Exhaustive studies of other aspidorhynchids from elsewhere in the world have been undertaken by Brito (1992, 1997), including a very detailed study of related South and central American species of *Vinctifer*. Based upon limited material, Brito regarded the Australian material as also being referrable to *Vinctifer*, a conclusion that is not supported by the present study.

ABBREVIATIONS. Ang = Angular; acv = foramen for anterior cerebral vein; ant. my. = anterior myodome; Apto = Autopterotic; art inf = articulation for 1st infrapharyngobranchial; Aspo = Autosphenotic; Boc = Basioccipital; br = branchiostegal ray; Bsp = Basisphenoid; ci = foramen for internal carotid artery; Cl = Cleithrum; Dpt-Exsc = Dermopterotico-Extrascapular; Dsp = Dentalosplenial; Dsph = Dermosphenotic; Epo = Epiotic; Epto = Epipterotic; Exo = Exoccipital; fm = foramen magnum; Fr-Pa = Fronto-Parietal; Hymd = Hyomandibular; hymdf = hyomandibular fossa; Ic = Intercalar; ica = foramen for internal carotid artery; Io = Infraorbital; jd = jugular depression; juv = foramen for jugular vein; l.Eth = Lateral Ethmoid; mdc = mandibular canal; Mx = Maxillary; Na = Nasal; Nerves:; I = olfactory nerve; II = optic nerve; III = common occular motor nerve; IV = pathetic nerve; V = trigeminal nerve; V+VII opht = opthalmic trunks of trigeminal and facial nerves; VI = abducens nerve; VII = facial nerve; VII jugm = jugulohyomandibular

trunk of facial nerve; IX = glossopharyngeal nerve; X = vagus nerve; oa = foramen for orbital artery; occa = foramen for occipital artery; Op = Operculum; Opo = Opisthotic; opp = opercular process; orb. = orbital cavity; Ors = Orbitosphenoid; Pdt = Predentary; pea = foramen for pseudo-branchial efferent artery; Pmx = Premaxillary; Po = Postorbital; Pop = Preoperculum; Post = Post-temporal; Pro = Prootic; pr psp = process of the parasphenoid; Psp = Parasphenoid; ptf = post-temporal fossa; Pts = Pterosphenoid; ptsp = pterosphenoid pedicule; Qu = Quadrate; Rart = Retroarticular; Ro = Rostral; Scl = Sclerotic Ring; Sclt = Supracleithrum; Soc = Supraoccipital; Sor = Supraorbital; Sop = Suboperculum; 1st vert. = first vertebra; Vom = Vomer.

All Queensland Museum specimens are identified with the prefix QMF. Material from other collections is identified by institution wherever they are referred to.

Class OSTEICHTHYS
Sub-class ACTINOPTERYGII
Division HALECOSTOMI (sensu Patterson, 1973)
Sub-division TELEOSTEI (sensu Patterson, 1973)
Family ASPIDORHYNCHIDAE Nicholson & Lydekker, 1889

Richmondichthys gen. nov.

DIAGNOSIS. Until further species are defined, the characters that define the species are also those that define the genus.

GENOTYPE. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891).

Richmondichthys sweeti (Etheridge Jnr & Smith Woodward, 1891)

Richmondichthys sweeti (Etheridge Jnr & Smith Woodward, 1891) pls 1-7.
Aspidorhynchus sp. Etheridge (partim), 1872; Jack & Etheridge Jnr, (partim), 1892.
Belonostomus sweeti Etheridge Jnr & Smith Woodward, 1891; Jack & Etheridge Jnr, 1892.
Vinctifer sweeti, Brito, 1997.

HOLOTYPE. MVP (Museum of Victoria) 12988, partial skeleton including posterior of head and bulk of body, Hughenden, central Queensland.

FORMATION. Mostly from the Toolebuc Formation, of Lower Cretaceous (Albian). Also from the Allaru Mudstone, of Lower Cretaceous (Albian).

DIAGNOSIS. Very large, exceeding 1.6 metres in length. Neurocranial roof with markedly asymmetrical fronto-parietals, dermopterotico-extrascapulars and post-temporals; rostral not extending beyond maxillary; premaxillary without teeth and short, not extending anteriorly as far as the dentalosplenial; circumorbital bones are extremely well developed; maxillary without teeth, set well anterior to orbit; predentary very small, edentulate; gill filaments extremely elongated; dentalosplenial deep anteriorly and very deep posteriorly, lacking teeth; lateral line scales greatly deepened; all scales heavily covered with ganoine, raised into heavy ridges and tubercles; ornamented ganoine also covers the outer bones of the head and is present on the larger elements of the fin rays.

MATERIAL. QMF1764, scales, Hughenden, CQ; QMF1841, scales, Hughenden, CQ; QMF1842, scales, Hughenden, CQ; QMF2296, partial body, Marathon Station, E of Richmond, CQ; QMF2389, scales, Hughenden district, CQ; QMF2389, partial skeleton, no locality; QMF2390, partial skull and skeleton, Hughenden district, CQ; QMF2437, scales, nr Hughenden, CQ; QMF2582, partial skeleton, Lydia Downs Station, N of Nelia, CQ; QMF5651, partial skeleton including parts of skull and anterior of body, Dingading Station, nr McKinlay, at MR 404304 McKinlay 1:250000 sheet, NWQ; QMF5660, partial skeleton, Dunraven Station, 48km NW of Hughenden, at Pelican Bore, CQ; QMF5661, partial body, Dingading Station, nr McKinlay, at por. 4, Par. Collins, NWQ; QMF5662, vertebrae, Hughenden, CQ; QMF5663, fragment with scales, Hughenden Station, Hughenden, CQ; QMF5664, fragment with scales, Hughenden Station, Hughenden, CQ; QMF5666, partial skeleton, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5667, fragment with ventral body scales, Meira Paddock, Boree Park Station, about 12km NW of Richmond, nr MR 622416 Richmond 1:250000 sheet, CQ; QMF5668, scales, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5669, partial skeleton, Pub Paddock, Borec Park Station, nr MR 627413 Richmond 1:250000 sheet, CQ; QMF5670, fragment with vertebrae and scales, Pub Paddock, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5671, partial skeleton, Pub Paddock, Boree Park Station, nrMR 627413 Richmond 1:250000 sheet, CQ; QMF5672, partial skeleton, Dingading Station, McKinlay, at por. 4, Par. Collins, NWQ; QMF5673, partial body, 22km N of Springvale Station, SE of Boulia, NWQ; QMF5674, partial body, 8km WSW of Marathon Station homestead, E of Richmond, CQ; QMF5675, partial skull and body, including gill filaments, Dingading Station, nr McKinlay, at MR 406306 McKinlay 1:250000 sheet, NWQ; QMF7568, partial skeleton including parts of skull and anterior of body, Marathon Station, E of Richmond, CQ; QMF7668, partial skull, no locality; QMF10608, neurocranium, Warra Station, NWQ; QMF12706, partial body, Stewart Creek, Dunraven Station, 3rd creek crossing from main road on track to Pelican Bore, CQ; QMF12856, neurocranium, no locality; QMF12904, partial body, Hughenden, CQ; QMF13412, neurocranium, Slashers Creek Station, NWQ; QMF13037, partial skeleton, Marathon Station, nr Richmond, CQ; QMF13413, neurocranium, Springvale Station, NWQ; QMF13711, partial skeleton, including partial skull and anterior of body,

Dunraven Station, Stewart Creek, unnamed tributary on S side, downstream from junction with Soda Creek and upstream from Pelican Bore, NW of Hughenden, CQ; QMF13726, scales, Dunraven Station nr Hughenden, CQ; QMF13727, partial skeleton, Stewart Creek, upstream from junction with Soda Creek, Dunraven Station, nr Hughenden, CQ; QMF13728, partial skeleton, bank of unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF 13729, partial skeleton, Stewart Creek upstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13731, partial skeleton, Stewart Creek downstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13734, partial skull, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13744, partial skeleton, Stewart Creek, upstream from junction with Soda Creek, Dunraven Station, nr Hughenden, CQ; QMF13745, partial skull, body and scales, Stewart Creek, downstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13746, partial skeleton, Stewart Creek, upstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13747, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13748, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13753, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13767, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13771, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13772, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13773, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13774, partial skull, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13775, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13776, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13777, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13778, partial skeleton, Dunraven Station, unnamed tributary of Stewart Creek, nr Hughenden, CQ; QMF13779, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13780, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13781, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF (unnumbered), partial skeleton, Rocky Waterhole, Flinders River, Julia Creek at L398 (QM collection register); QMF13787, neurocranium, Dunraven Station, N of Hughenden, CQ; QMF13788, partial skeleton and scales, Stewart Creek, downstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13789, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13790, partial skull, Stewart Creek, upstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13791, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13793, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13794, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13795, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13796, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF14339, partial body, Boree Park, W of Richmond, CQ; QMF18040, partial skeleton, Marathon Station, nr Richmond, CQ; QMF18115, partial skull, Flinders River crossing, W of Marathon Station homestead, Allaru Mudstone, CQ; QMF18153, body and skull fragments, 1.4km S of Jacks Bore, Canary Station, SE of Boulia, NWQ; QMF15328, skull fragment, Pelican Bore area, Dunraven Station, CQ; QMF18218, partial skull and anterior of body, NE of Canary Station homestead, SE of Boulia, NWQ; QMF18253, partial body, 2.6km S of Canary Station homestead, in lambing paddock, SE of Boulia, NWQ; QMF18295, skull and anterior of body, old Council quarry, 5km S of Flinders River, W of Richmond, CQ; QMF18603, partial skeleton, 2km E of Jacks Bore, Canary Station, SE of Boulia, Toolebuc, NWQ; QMF18898, almost complete skull and post-cranial skeleton, 20km W of Richmond, nr Old Richmond/ Maxwelton Highway, CQ; QMF25074, partial skull, Flinders River, at QM collection locality L815, Allaru Formation, CQ; QMF25077, partial skeleton, Flinders River at QM collection locality L815, Allaru Formation, CQ; QMF25331, body scales, Canary Station, nr Boulia, NWQ; QMF41492, scales, Boree Park Station, nr Richmond, CQ; QMF41493, partial skull, Boree Park Station, nr Richmond, CQ; QMF41494, partial skull, Boree Park, nr Richmond, CQ; GSQF12904 (Geological Survey of Queensland Collection), scales, Hughenden, CQ

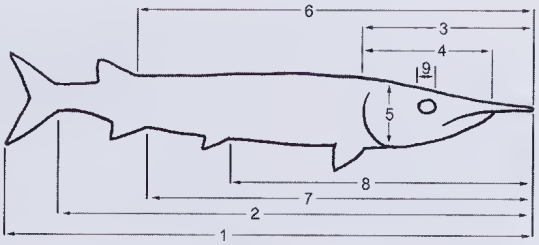

FIG. 1. Hypothetical aspidorhynchid telcost (from Brito, 1997) illustrating parameters applied in Table 1.

DESCRIPTION. *General.* General body shape is elongate and sub-cylindrical, but much deeper than broad. *Richmondichthys* was a very large fish, with preserved individuals exceeding 1.6m in length and with fragments of even larger individuals preserved. Body depth exceeded 27cm. The body is deepest just posterior to the head, gradually reducing in depth to the caudal peduncle where the depth is about 25% of maximum depth. Table 1 (linked to Fig.1), provides measurements for the most complete of the *R. sweeti* specimens (QMF18898) compared

TABLE 1. Comparative morphometric values (cm). (See Brito, 1997 for information on *V. comptoni* specimens)

	1	2	3	4	5	6	7	8	9
R. sweeti (QMF18898)	-	147.9	34.2	35.1	14.5	118.2	114.1	94.4	4.6
V. comptoni (USU 49)	75.0	70.0	19.0	13.0	8.0	55.0	54.6	47.0	1.4
V. comptoni (USU 07)	12.0	11.6	5.0	1.6	0.9	8.7	8.4	-	-
V. comptoni (FMNH PF 13486)	27.0	26.0	8.8	-	1.5	21.5	21.3	-	-

with those for specimens of *V. comptoni* provided in Brito (1997).

The head is long and narrow. Premaxillaries are extended anteriorly but do not reach as far forward as the dentalosplenials, let alone the predentary. The head represents approximately one-quarter the length of the fish. Its length is more than twice its maximum depth (Figs 2-4). The quadrato-mandibular articulation is situated anterior to the level of the front of the orbit (Fig. 3).

The scales are heavily covered with ganoine. Those along the flanks, especially anteriorly, are much deeper than dorsal and ventral scales. A total of 82 rows of scales are present in QMF18898 (Fig. 5) between the posterior border of the supracleithrum and the posterior of the caudal peduncle. As defined in the scale formula outlined by Westoll (1944) and applied by Brito (1997), the pelvic, anal, dorsal and caudal fins are located along the body as follow:

$$\frac{\qquad\qquad 61 \qquad\qquad}{37 \qquad 55 \qquad 69} \qquad 82$$

It is likely that the pelvic, anal and dorsal fins were reclining backwards and that the caudal fin was relatively large and forked as in other aspidorhynchids.

Cranium. The endocranium in *Richmondichthys* is well ossified in more mature individuals (Figs 6-8). It comprises a bony box with anterior and posterior moieties united by the parasphenoid below and the frontalo-parietal above, with contiguous elements firmly sutured and with such sutures variably tending to disappear with age, similar to those in other members of the Aspidorhynchidae (Brito, 1992).

The following measurements have been derived mainly from QMF7568.

Length, from the anterior of the nasal fossa to the posterior border of the post-temporal, 19.4cm; from the anterior of the nasal fossa to the posterior border of the basioccipital (lateral view), 14.3cm. Breadth, at the level of the post-orbital processes, 5.5cm. Depth, at the anterior of the basisphenoid, 3.1cm.

These measurements allow a broad comparison to be made with similar measurements in *Vinctifer comptoni* especially as these relate to proportions calculated by Brito (1992) for that species. The endocranium in *Richmondichthys* is very long, being 6.2 × as long posterior to the nasal fossa as the maximum depth (c.f. 4.5 × in *V. comptoni*). The nasal fossa is relatively short, representing 6% of the endocranial length in lateral view (20% in *V. comptoni*). The orbit is comparatively large (35.6% of the same measure c.f. 32% in *V. comptoni*) while the post-orbital region is very large, being 57.6% of the lateral endocranial length (48% in *V. comptoni*).

Ethmoid Region. Only the posterior of the ethmoid region is exposed in one individual, QMF568. It is well ossified and forms the floor and posterior wall of the nasal fossa. A median septum separates the fossa, while its upper extent is limited by the anterior of the frontals and the posterior of the rostral; the anterior of the nasal fossa appears to be contained by the ethmoid itself.

The posterior of the lateral ethmoid bears a large, horizontal ridge directed posteromedially towards the orbitosphenoid, above the parasphenoid, presumably supporting the olfactory nerve (I) and capping the anterior myodome. The foramen for the orbitosphenoid vein is present at the base of the large ridge and there is an articulation surface anteromedially on the ethmoid base for the palatine. Anteriorly, the ethmoid region encircles a posterior extension of the premaxillaries.

Orbito-Temporal and Otic Region. The posterior surface of the orbit is penetrated by a large number of foramina for nerves and blood vessels to the mandible and the anterior of the cranium.

The orbitosphenoid is fully ossified in those individuals in which it is visible (QMF7568 and QMF13412). It comprises the posterodorsal roof of the orbital cavity, fanning anteriorly and well separated from the posteromedial processes of the ethmoid region. It is sutured laterally to the pterosphenoids. In anterior view, the orbitosphenoid extends a medial plate anteriorly to form the base of the canal for the passage of the

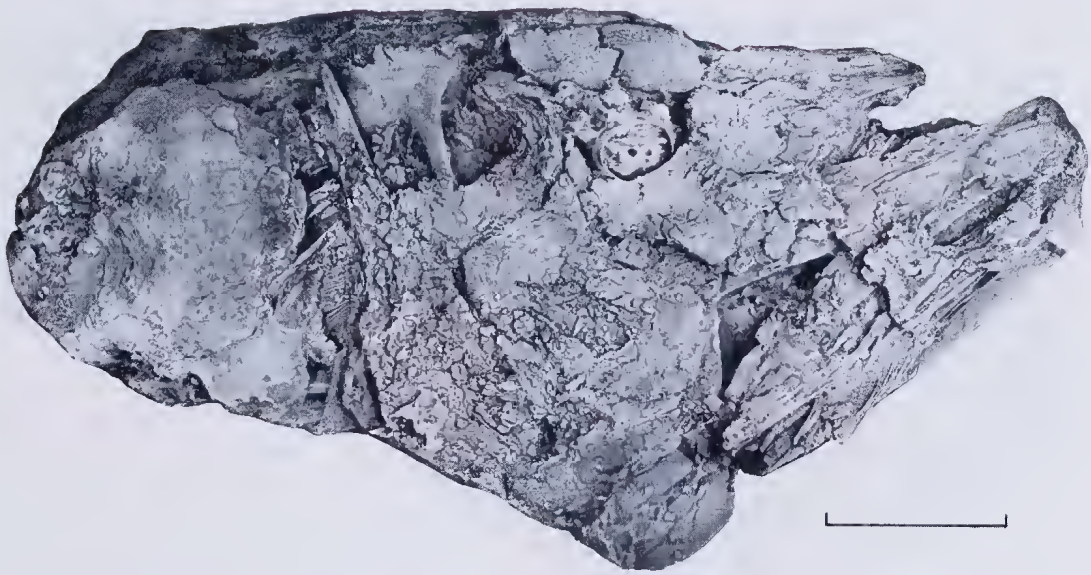

FIG. 2. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF13711, lateral view of right side of head. Scale bar = 5cm.

olfactory nerve (I) and the roof of the large opening for the optic nerves (II). There is no evidence of the presence of a foramen for the passage of the anterior cerebral vein.

The pterosphenoid forms the posterolateral part of the posterior orbital wall. It is supported dorsally by the frontal and extends to join with the autosphenotic laterally and with the base and dorsal wing of the basisphenoid. It is excluded from lateral contact with the prootic by the autosphenotic and the parasphenoid. There is a prominent bony crest forming a pterosphenoid peduncle, subparallel to the ventrolateral rim of the opening for the orbital nerve. Medially and floored by the pterosphenoid peduncle is a relatively large foramen for nerve III, close to the suture with the wing of the basisphenoid. Close to the internal border of the pterosphenoid peduncle and just above the basisphenoid suture is a foramen interpreted as that for nerve IV. This appears to be separated fairly widely from another small foramen near the lateral extent of the pterosphenoid peduncle, possibly for the anterior cerebral vein. The lateral extension of the peduncle surrounds and provides the rim of the tigeminofacial orifice and anterodorsally to this is penetrated by nerve V.

The basisphenoid has a stalk that meets the dorsal surface of the parasphenoid and slopes posterodorsally, separating the left and right moieties of the posterior myodome. The base of the basisphenoid has dorsolateral extensions that form the floor and ventrolateral walls of the large orifice for the passage of the optic nerves(II) and that meet a moderately large process of the pterosphenoid.

The autosphenotic is relatively small and triangular and caps the lateral extent of the orbitotemporal and otic regions. The dorsal face is in contact with the cranial roof in the region of the dermosphenotic but is not united with it. The anterior face is slightly curved, forming the posterodorsal extent of the orbit with both the pterosphenoid and the lateral process of the parasphenoid. Posterolaterally, the autosphenotic

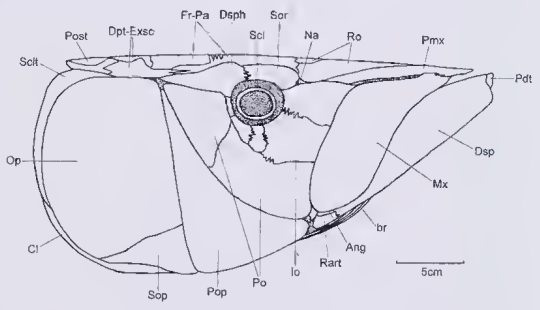

FIG. 3. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891). Reconstruction of the head in lateral view, based primarily on QMF13711 and QMF18898. Scale bar represents 5cm.

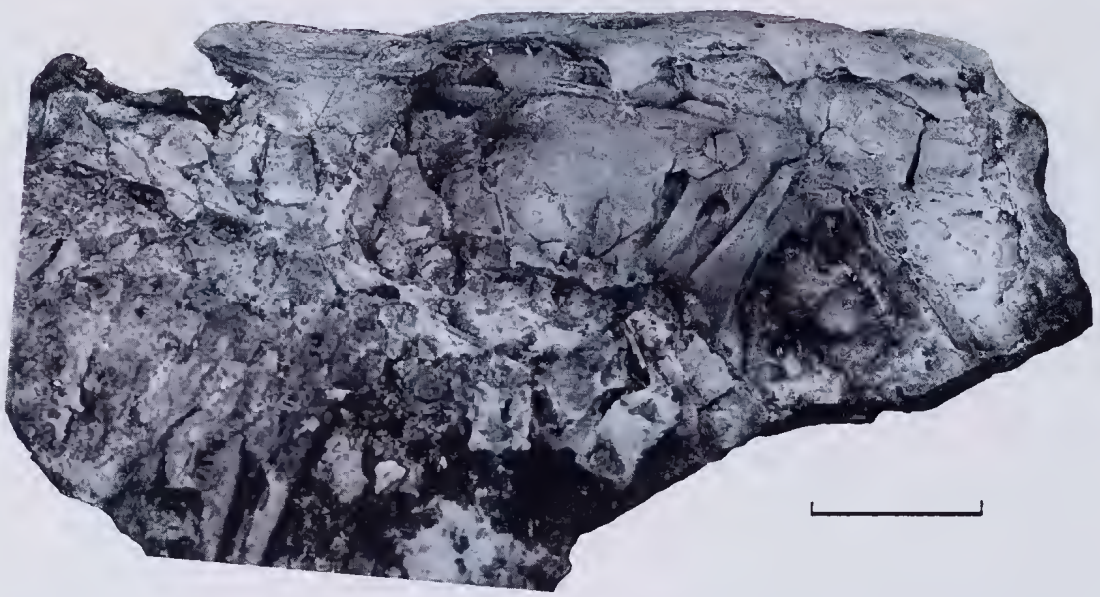

FIG. 4. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF13711, lateral view of left side of head. Scale bar = 5cm.

meets the prootic and bears a large depression that represents the anterior extent of the articular fossa for the hyomandibular.

The prootic is a large, complex bone that forms the bulk of the floor and walls of the neurocranium, reaching from the back of the postorbital processes to the cranial roof and the lateral walls and back of the posterior myodome. In lateral view, the prootic extends to meet the basioccipital, the suture with which is sometimes partially or completely obscured and difficult to identify. Similarly, the suture separating the prootic and opisthotic is not able to be identified in available specimens.

In lateral view, the otic region carries the bulk of the large, horizontal, hyomandibular fossa, which extends from the back of the postorbital process below the cranial roof to the abutment of the autopterotic. The fossa is slightly hour-glass shaped. Immediately below the hyomandibular fossa are several well developed and large foramina – the large opening for the passage of the jugular vein into the trigemino-facial chamber; the foramen for the jugulohyomandibular trunk of the facial nerve, midway along the prootic; the slightly smaller foramen for the glossopharyngeal nerve (IX), situated near the basioccipital suture within the jugular depression; and the larger foramen for the passage of the vagus nerve (X), opening at the dorsal end of the otico-occipital suture. The depression for the jugular vein is very distinct, especially in the area of the foramen for the jugulohyomandibular trunk of nerve VII. The extracranial trigemino-facial chamber opens backwards through the large oriface or the passage of the jugular vein. The space also appears to provide a communication with the cranial cavity for the profundus, trigeminal (V) and facial (VII) nerves. The orbital opening of the trigemino-facial chamber is divided by the pedicule of the pterosphenoid with the median opening accommodating the ophthalmic rami of the trigeminal and facial nerves (V + VII opht) and a lateral opening possibly for the trigeminal and facial nerves and for the jugular vein and orbital artery. The profundus nerve appears to proceed through a foramen more anterodorsally, near the suture between the pterosphenoid and the orbitosphenoid, close to a foramen believed for the median cerebral vein. The ventral border of the prootic, immediately behind the parasphenoid process contributes to the articulation for the first infrapharyngobrachial, although the bulk of the articulation is on the parasphenoid process itself. The articulation of the infrapharyngobrachial has not been observed in any specimen.

The opisthotic is generally fused to the prootic and the suture is not easily observed. It extends backwards from behind and above the large

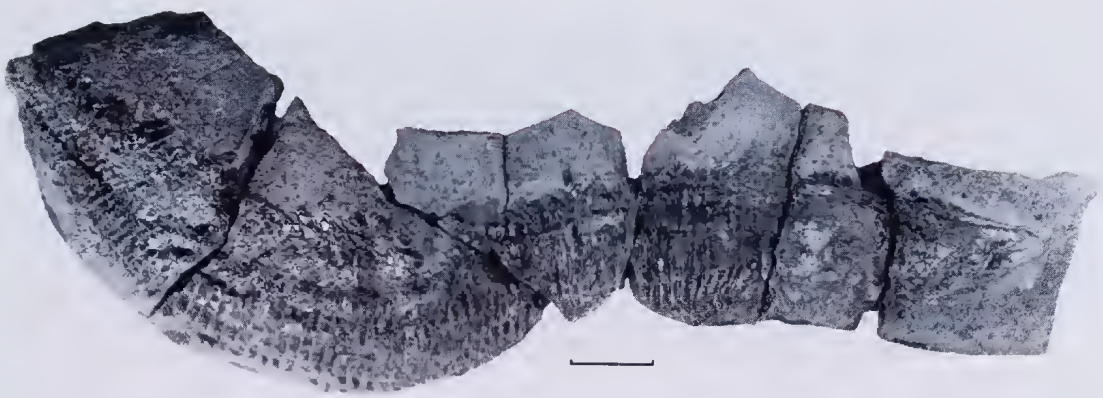

FIG. 5. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF18898, almost complete skeleton from right side. Scale bar = 10cm.

foramen for the glossopharyngial nerve (IX) and just reaches that for the vagus nerve (X). The bone was much smaller than the prootic.

The autopterotic is very small, developed above the back of the opisthotic and lateral to the even smaller epipterotic. It has a well defined and robust process directed posteriorly to be sutured with the intercalar process. The autosphenotic is totally independent of the dermal bones of the cranium.

The intercalar is prominent, extending posteriorly as a large, flattened and vertically expanding process from the junction of the opisthotic and autosphenotic. It is fused laterally to the process of the autosphenotic and extends well beyond the vertebra fused to the basioccipital. It is partially covered by the extrascapular and the post-temporal and bears a large foramen anteriorly, above the suture with the autopterotic.

Occipital Region. The bony mass of the occipital region is limited anteriorly by the suture with the prootic (the otico-occipital fissure), to include the whole of the foramen for nerve X and posteriorly by the fusion of the basioccipital and the first vertebra.

The basioccipital is defined laterally by well defined sutures. It comprises the ventral and lateral margins of the occipital region. The ventral margin extends slightly anterior to the foramen for the glossopharyngeal nerve (IX). It is united with the prootic and opisthotic by an oblique suture. The basioccipital has not, as yet, been exposed in posterior view. Posterodorsally, it meets the exoccipital. Occasionally, a small foramen is present above and towards the back of the parasphenoid for the passage of the occipital artery. The first vertebra is firmly fused to the basioccipital and forms part of the endocranium.

The exoccipital contributes to the dorsolateral part of the occipital region and to the posterior surface. It extends from just above and behind the foramen for the vagus nerve (X) and is sutured deeply with the basioccipital anteroventrally and posteriorly fused with the first vertebra. Each exoccipital is extended posterodorsally into an arch, comparable with that of the first vertebra and deeply sutured to it.

The epiotic forms the posterior margins of the post-temporal fossa. It is positioned between the exoccipital and the posterior process of the intercalar and contributes to the posterodorsal border of the endocranial roof. It is deeply sutured to the exoccipital posterodorsally and is penetrated by a number of foramina, the largest of which is interpreted to be for the posterior cerebral vein.

The supraoccipital is largely hidden by the extrascapular in most specimens. It is a small bone, firmly fused with the epiotic and has a pair of posterodorsal processes that overlap the arch structure of the exoccipitals.

Dermal Bones of the Anterior Aspect of the Endocranium. The parasphenoid comprises a narrow veneer of bone under the neurocranium. It is very long anteroposteriorly, extending from near the front of the ethmoid region to just posterior to the level of the foramen for the vagus nerve (X). It appears to contribute medially to the posterior of the rostral tubes and is anteriorly broadened and flattened between the ethmoids. It does not appear to bifurcate in this region to envelop the vomer and its relationship with the vomer has not been observed. The parasphenoid is slender below the orbit, flattened laterally and

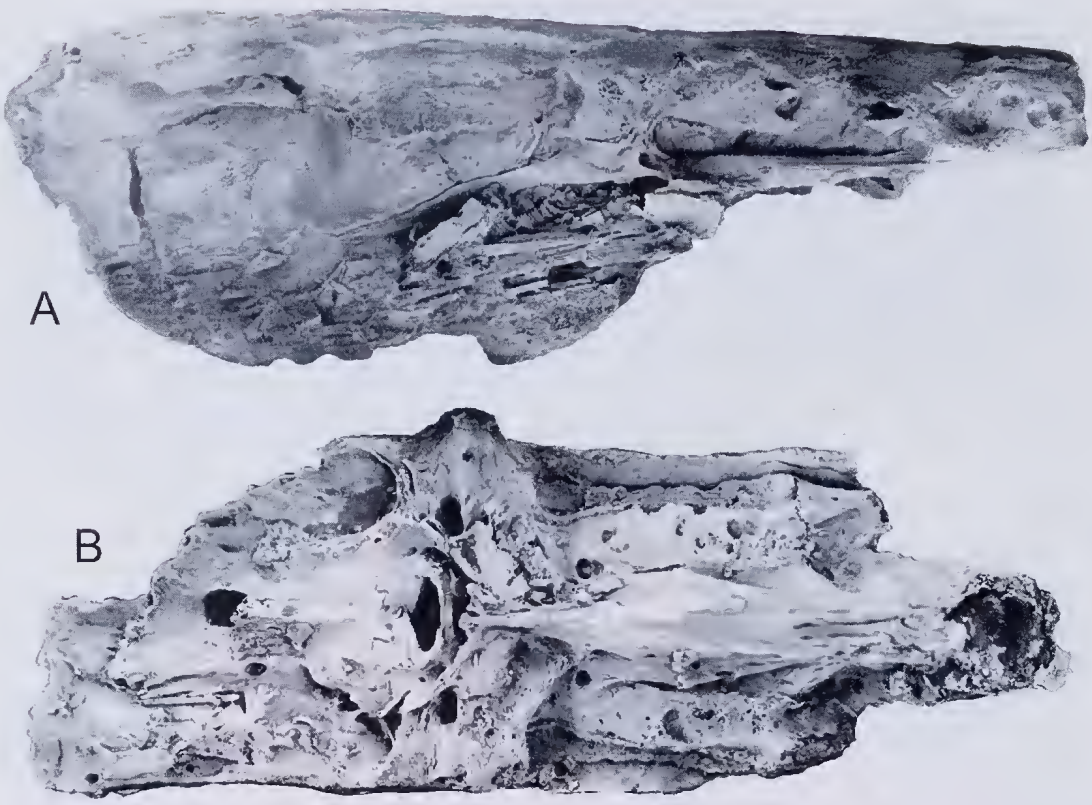

FIG. 6. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) neurocranium. A, lateral view of right side, QMF7568, × 0.65; B, ventral view, QMF13412, × 1.75.

dorsally crested. It then presents a concavity towards the back of the orbital cavity that curves dorsally to about the level of the postorbital processes before extending posteriorly and flattening dorsoventrally below the otico-occipital region.

A wing-like process is developed on each side of the parasphenoid below the postorbital processes. These are directed ventrolaterally to below the autosphenotics, with the anterior margin of the parasphenoid process forming the border of the posterior myodome and the posterior margin scalloped out to contribute to the foramen for the passage of the internal carotid artery. Another foramen is present in each wing, well beyond the midline and these are believed for the pseudobranchial efferent artery.

The parasphenoid is totally devoid of teeth and lacks any trace of a basipterygoid process.

The vomer has not been observed in any specimen yet found. It is possible that it is present within the anterior broadening of the parasphenoid in F7568. However, no sutures are evident and there is no evidence for any vomerine teeth.

Rostral Region. The premaxillaries comprise the major elements of the anterior of the rostral region. They are ornamented with fine, longitudinal striae, where exposed. Posteriorly, the bone is inserted deeply below other dermal bones and forms the rostral tube that is fitted into the endocranial ethmoid region. Anteriorly, the premaxillaries are not greatly tapered and terminate posterior to the junction of the dentalosplenial and the predentary. Ventrally, it is believed that the premaxillaries are underlain by the parasphenoid and possibly the vomer; posteriorly, each is encased by the rostral above and the dorsal margin of the maxillary. Contact with the nasal does not appear to occur. The premaxillaries are edentulate where they have been observed.

The rostral is a large bone, transversely convex and much longer than wide, covering the posterior of the premaxillaries and overlapping the frontals. It is ornamented by ridges of ganoine.

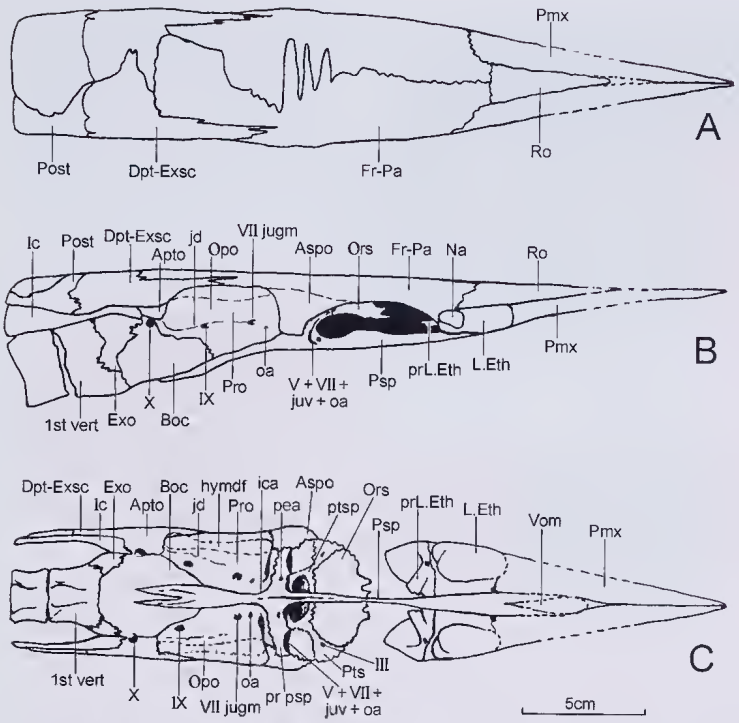

FIG. 7. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891): Reconstructed neurocranium based primarily on QMF7568, QMF13711 and QMF13412. A, dorsal view; B, lateral view; and C, ventral view. Scale bar = 5cm.

The nasal is a small bone, limited dorsally by the rostral and appears to be limited anteriorly and posteroventrally by the first infraorbital and posterodorsally by the supraorbital. Association of the infraorbital canal with the nasal has not been observed in any of the available specimens. The anterior of the supraorbital canal traverses the nasal.

Cranial Roof. Apart from the rostral region, the cranial roof comprises a series of bones identified as the fronto-parietals, dermopterotico-extrascapulars and the post-temporals.

The fronto-parietals comprise the largest bones of the cranial roof. They extend from the rostrals to the dermosphenotico-extrascapulars, just above the front of the opercular. In dorsal view, the width is almost constant from front to back, although there is a slight broadening above the rear of the orbit. The bones are markedly asymmetrical, with the mediodorsal suture deeply interdigitated and set mainly to the left but occasionally to the right of the midline. The frontals have usually been firmly welded to the parietals but sutures with the latter are sometimes visible. The surfaces are heavily ornamented with ridges and tubercles of dentine, generally radiating anteriorly, posteriorly and medially from points on the frontals, above the autosphenotics. Laterally, the fronto-parietals are shallowly grooved to accommodate the upper margins of the uppermost postorbital and the supraorbitals.

The dermopterotico-extrascapulars comprise a pair of gently arched bones that, like the fronto-parietals are markedly asymmetrical and that have a well-defined mediodorsal suture. Variable ridges and tubercles of ganoine radiate on the surface from anterolateral loci. Lateral grooves accommodate the upper margin of part of the dermosphenotic.

The post-temporals are similar to the dermopterotico-extrascapulars and comprise a pair of markedly asymmetrical, gently arched bones that are anteriorly overlain by the extrascapulars and that meet one another along a deeply overlapping and broadly undulating mediodorsal suture. Ornamentation is of strong ridges and tubercles of ganoine radiating from loci mid-way along the lateral margins.

Cheek. The orbit is surrounded by the infraorbital series and by the dermosphenotic and supraorbital. Two large postorbital plates and the preoperculum complete the cheek bones. The cheek bones are largely unornamented by ridges and tubercles of ganoine except for the supraorbital and dermosphenotic where coarse ornamentation is present in rows paralleling the dorsal margins. The sclerotic ring appears to comprise no more than two plates.

The dorsal margins of the cheek bones fit into a groove along the dorsolateral margin of the neurocranium, forming a hinge along which the cheek bones can be rotated outwards.

The infraorbital series comprises five bones, generally increasing in size from a small rectangular element posterior to the orbit, around the ventral and anterior rim of the orbit. The large,

FIG. 8. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) neurocranium. A,C, dorsal and posterior views of QMF10608, × 1.4; B, dorsal view of QMF7568, × 0.45.

uppermost anterior element reaches well in front of the nasal and has broad contact with the maxillary. The second infraorbital is equally large and also has broad contact with the maxillary. Remaining infraorbitals (Io 3-5) complete the ventral and posterior margins of the orbit and broadly contact the postorbitals.

The supraorbital is a robust element approximately twice as long as it is high. It forms the anterodorsal margin of the orbit and abuts the frontal, reaching anteriorly to the nasal and the rostral.

The dermosphenotic is very long and robust, extending posteriorly from its suture with the supraorbital above the middle of the orbit to a point above the dorsal extremity of the preoperculum. It has a long abutment with the frontal and the dermoptcrotic.

The postorbitals comprise two very large elements that cover the anterior margin of the preoperculum. The ventral element makes broad contact with the maxillary and meets Io 2-4.

The preoperculum is an extremely large, triangular bone with the posteroventral angle approximately 90°. The preopercular canal has not been observed in any specimen.

Opercular Series. No interoperculum is present.

The operculum is a large, heavy element, subovate in outline with a slightly indented ventral margin, a straight anterior margin and near right angled anteroventrally. The facet for the articulation with the hyomandibular is situated anterodorsally. The surface is heavily ornamented with numerous, irregular and concentric ganoine ridges and tubercle rows, centred approximately above the hyomandibular facet.

The subopercular is a moderately large bone, filling the space between the preoperculum and the operculum and ventral to the latter. It is quadrant-shaped and its surface is heavily ornamented with low, irregular, concentric ganoine ridges and tubercles around a centre near the anterodorsal extremity. Areas overlapped by other bones lack ganoine.

Some 13 branchiostegal rays are present below the posteroventral angle of the mandible.

No gular plate is present.

Upper Jaw. The maxillary is a large, boomerang-shaped bone that is much more developed in its posterior part than anteriorly. It is positioned considerably in advance of the orbit with the posteroventral margin remaining well anterior to the anterior of the orbit and not extending to the preoperculum. The posterior portion is thin and broadly covers the posterodorsal area of the mandible. The anterior presents a weak dorsal process that articulates with the premaxillary. No teeth are present. The bone is coated with largely

featureless ganoine extending backwards and dorsally from the oral margin.

No supramaxillary is present.

Lower Jaw. A predentary is present as a medial element at the extreme anterior of the mandibles. It is edentate and is a tiny bone deeper than long. The oral border is much shorter than the depth of the bone.

The mandible has a relatively elevated and very deep symphysis, united in its upper moiety with the predentary by a near vertical suture. The coronoid process is virtually non-existent and is covered by the maxillary in most specimens. The lateral face is largely formed by the dentalosplenial. The angular is relatively large but is almost completely covered by the posterior of the maxillary. The articular facet for the quadrate is formed at the base of the coronoid process by the angular and retroarticular on the upper surface of the mandible, at the base of the coronoid process. A short posterior process present behind the articular facet is formed by the articular and the retroarticular. The dentalosplenial and the angular are crossed longitudinally by the mandibular canal which has surface expression on the dentalosplenial as a shallow groove towards the ventrolateral margin. Ventrolaterally and around the anterior border, the mandible is heavily ornamented with ganoine ridges and tubercles, generally arranged longitudinally. The remainder of the lateral surface is coated with smooth ganoine.

The mandible is edentate.

Hyoid Arch Area. The mandibular-neurocranial connection is through the hyomandibular and the quadrate There is no evidence for the presence of a symplectic.

The hyomandibular is upright with the articular facet for the junction with the neurocranium elongate and near horizontal and with its distal extremity slightly curved anteriorly. The lateral surface is strengthened by a prominent ridge that separates a deep anterior portion that appears to abut the metapterygoid. The posterior border carries a prominent opercular process towards its top. The body of the bone is penetrated by the large foramen providing passage for the hyomandibular trunk of the facial nerve. The distal extremity has not been well exposed in any specimen but apparently provides broad contact with the quadrate anteroventrally and with the proximal ceratohyal towards the back. There is no evidence for the presence of an interhyal and the distal ceratohyal, hypohyal and basihyal have not been exposed in any of the available specimens.

The quadrate is a large, triangular bone but the dorsal extremity is not exposed in any of the available material. Anterodorsally, the quadrate overlies the ectopterygoid and is assumed to contact the metapterygoid dorsally. It also has broad contact with the hyomandibular dorsally. The articular condyle is oriented ventrally and anteriorly.

The autopalatine is almost completely obscured in all specimens, as are the metapterygoid and entopterygoid. The ectopterygoid is visible only posteriorly, where its ventral border is almost horizontal and the whole bone is essentially straight and tapering anteriorly. The bone is edentate.

The branchial arch is imperfectly preserved. Each element of the gill arches bears very numerous, extremely elongated gill filaments directed away from the arch (Fig. 9). Slightly more robust and elongated gill rakers occur anteromesially.

Postcranial Skeleton. The vertebral column has not been completely exposed in any specimen, making it impossible to indicate the number of individual vertebrae. Each centrum is amphicoelous and ovate in anterior view, being slightly higher than long. Each bears a small central foramen, the remnant of the notochord. The centrum is otherwise entirely ossified and only very slightly constricted longitudinally. Length of each centrum is about equal to the width. The lateral surface is smooth (Fig. 9). In section, the centrum possesses very fine radiating laminae of bone, separated by unossified areas. Neural arches are attached and bear prezygopophyses and postzygopophyses and support elongate, posteriorly directed neural spines, at least anteriorly in the body. In this area, such spines consist of separate lateral elements. Anterior neural arches are very elongate, occupying the entire length of each centrum , with the spines emerging above the middle of the centrum. Very short epineural spines are present anteriorly, fused firmly at the base of each neural spine. Anterior parapophyses are fused to the centra ventrolaterally. In more posterior vertebrae, haemal arches appear slender and at least in some individuals, both these and the neural arches are not fused to the centrum. The ventral surface of anterior vertebrae bears a median, longitudinal ridge separated from the parapophyses by shallow depressions.

The pectoral girdle is only partially exposed in all specimens. The supracleithrum extends from

FIG 9. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891). A, gill elements, QMF5675, × 0.7; B, portion of vertebral column, QMF7568, × 1.6.

near the dorsal limit of the convex upper margin of the operculum ventrally to about one-half way down its posterior margin. Exposed portions are ornamented with irregular ridges and tubercles of ganoine, arranged parallel to the dorsoventral axis of the bone. The cleithrum is a much larger element, overlapped dorsally by the supracleithrum and extending around and under the posteroventral and ventral margins of the operculum and suboperculum. It is markedly concave anteriorly and exposed portions are ornamented with ganoine. The scapula and coracoid are almost completely obscured but the former is facetted to carry the pectoral fin. Other bones of the pectoral girdle are unknown.

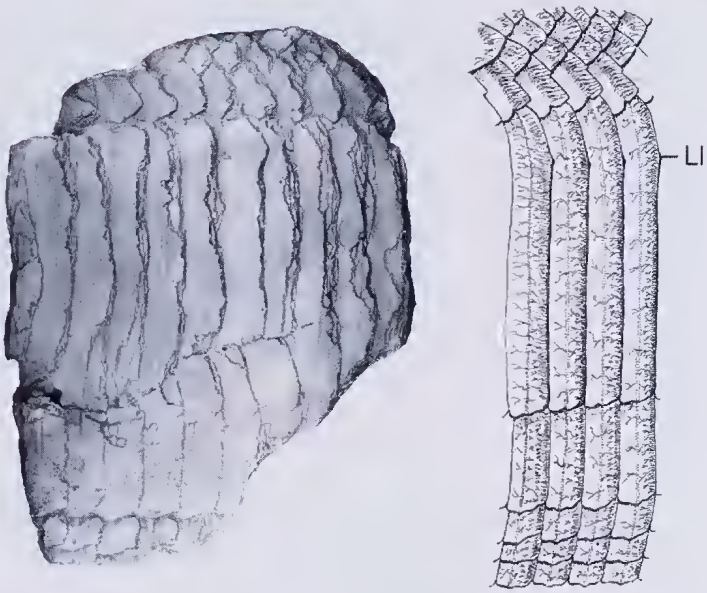

FIG. 10. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) mid-body scales with dorsal wall uppermost. A, GSQF12904; B, reconstruction (by T. Lees); both × 0.3.

Remains of the bases of all fins are preserved in only one specimen, QMF18898, and the formula for the fin positions above have been based upon this. Some exposed basal elements of all fins appear to have been coated with ganoine.

The pectoral fin appears to have seven rays, with the first smaller than the second, the latter being the largest ray in the series. At least proximally, the rays bear ornamentation of ganoine. As the rays broaden distally, the longitudinally orientated ganoine ridges are increased by insertion of additional ridges. The fin is moderately long, at least equal to two-thirds the depth of the anterior expanded flank scales. The pelvic, anal, dorsal and caudal fins are known from only remains of their bases.

Scales. The scales are heavy, strong and conspicuous and are the most commonly preserved parts of the skeleton (Figs 5,10). They are thickly ornamented with ganoine pits, low ridges and tubercles. Anterior and mid-body scales of the median flank series are very large. Individual lateral line scales in large specimens are up to 14.5cm deep and 2.3cm long. Table 2 details the depths of flank scales along the body in QMF18898.

TABLE 2. Depth of flank scales (cm) where: A measures scale immediately ventral to lateral line scale; B measures lateral line scale; and C measures maximum observed body depth.

Character	Near Head (Row 4)	Above Pelvic Fin	Above Anal Fin	Front of Caudal Fin
A	5.0	2.7	1.0	0.8
B	10.6	11.6	7.9	5.6
C	21.4	22.1	16.6	10.1

Each median flank scale is slightly laterally convex with the convexity increasing dorsally. The posteroventral border is rounded. The ventral border, while generally convex, has a broad mesial process. The posterior margin is finely and irregularly serrate where the low ridges of ganoine project. The upper margin is pointed, with the apex posterior to the apex of the scale. The leading edge is smooth. A heavy ganoine ridge runs down the axis of the scale and this is usually paralleled by a second, less well defined ridge, just anterior to it.

The major ridge is often ornamented with tubercles, while the other ridge sometimes degenerates to a series of tubercles only. The anterior ganoine is smooth or only very slightly pitted or tuberculate. Posterior to the main ridge, irregular ganoine ridges run generally anteroposteriorly, often bifurcating or reuniting but give a general impression of subparallel, longitudinal ornamentation. Ornamentation is heavier dorsally. The lateral line is marked by a heavier, longitudinal plication, close to the dorsal limit of the scale.

TABLE 3. Comparison of Aspidorhynchid genera. Information on *Vinctifer*, *Belonostomus* and *Aspidorhynchus* is based on revised diagnoses and descriptions in Brito (1997).

Characters	*Richmondichthys*	*Vinctifer*	*Belonostomus*	*Aspidorhynchus*
Premaxillary teeth	Absent	Absent	Present	Well developed
Maxillary teeth	Absent	Present	Present	Present
Supramaxillary	Absent	Absent	Present	Present
Maxillary	Very expanded	Large	Slender	Slender
Premaxillary	Short	Attenuated	Very attenuated	Attenuated
Neurocranium	Fused	Fused	Fused	Unfused
Parasphenoid	Edentulate	Edentulate	Toothed	Toothed
Anterior infraorbitals	Much expanded	Unexpanded	Unexpanded	Unexpanded
Predentary	Minute	Small	Very attenuated	Small
Lateral line scales	Very deep	Deep	Somewhat deep	Shallow
Scale ganoine	Very ornamented	Unornamented	Unornamented	Absent

Ventral to the main flank scales are at least four and possibly up to six rows of progressively smaller scales. In large individuals, anteriorly the uppermost are up to 5cm deep. The next scales row are up to 1.8cm deep, those in the third row are up to 1.5cm deep, while in the fourth row they approach 1cm deep. The uppermost of these ventral scales has very similar structure and ornamentation to the main flank scales. Lower scales generally have little or no ornamentation, other than traces of the median ridge and are subovate in shape but have a distinct peg arranged axially along the dorsal margin.

Dorsal scales above the main flank scales also appear to be in no less than four rows anteriorly. Unlike the ventral series where scales are arranged in near vertical rows, those above the main flank scales are angled anteriorly. In outline, scales of the first row are similar to the main flank scales but have a ventral emargination rather than a peg. The median ridge is less strongly defined but minor ornamentation is similar. In large specimens, the lowermost dorsal scale is up to 2.8cm deep. Scales above this row are inserted to leave a broadly convex posterior margin but are otherwise rhomboidal in shape. Little trace remains of a median ridge and ornamentation consists of anteroposteriorly arranged , irregular ganoine ridges. Occasional heavy tubercles are present. In depth, the dorsal scales decrease in size dorsally and in large individuals measure up to 2cm, 1.9cm and 1.7cm within each row.

More posteriorly along the body, depth of the large flank scales gradually decreases and near the base of the caudal fin, all scales are of a similar size, are rhomboidal and are arranged in an imbricated pattern. Ornamentation has been reduced to a posterior, longitudinal keel with subparallel minor ridges. Up to 82 rows of scales are present in the flank series.

DISCUSSION

Brito (1997) has undertaken a major revision of the Family Aspidorhynchidae and referred the Australian material, previously ascribed to *Belonostomus sweeti*, to the genus *Vinctifer*. Fragmentary aspidorhynchid remains from Cretaceous sediments at Hughenden Station in central western Queensland and referred by Etheridge (1872) to *Aspidorhynchus* sp. included parts of large body scales that are ornamented with ridges and tubercles of ganoine. This material was referred to the species *Belonostomus sweeti* by Jack and Etheridge Jnr (1892). Clearly, this material is not referable to *Aspidorhynchus*, which is shown by Brito (1997) to lack ganoine on its scales. Similarly, it is not referable to either *Belonostomus* or *Vinctifer* both of which have unornamented ganoine on their principal and other body scales. However, rugosity may be present on the scales in some *V. comptoni*, as described by Jordan (1921). The Hughenden material is here referred to the new genus, *Richmondichthys*, although non-diagnostic specimens can only be regarded more generally as undetermined aspidorhynchids. Table 3 provides a comparison of major morphological characters within the genera of the family, based on those features that are present in all of them. Figure 11 compares the heads of the aspidorhynchids.

In many of the earlier reconstructions of *V. comptoni*, the extent of the premaxillary spine was not recognized e.g., in that illustrated in Jordan (1921). The retracted nature of this feature in R.*sweeti* might thus be supposed to reflect a

similar accident of preservation, with an attenuated spine broken off and lost during preservation. Close examination of the tips of the premaxillaries in QMF18898 shows that this specimen presents the entire extent of the spine and that the termination of this structure is posterior to the anterior extent of the lower jaw.

In ascribing *B. sweeti* to *Vinctifer*, Brito (1997) believed the species to be close to but much larger than the type species, *V. comptoni* from the Albian Santana Formation, Jardim, Ceara, Brasil. Temporal and geographical distribution of *V. comptoni* is recorded by Brito (1997) as also being from the Santana of the Araripe Basin, the Aptian/Albian Codo Formation of the Parnaiba Basin, the Aptian Muribeca and Albian Riachuelo Formations of the Sergipe and Alagoas Basins and in the Aptian Apon Formation of Venezuela and the Albian Morelos Formation of Tepexi de Rodriguez, Puebla, Mexico.

Apart from *V. comptoni*, to which Brito (1997) referred the recently described *V. punctatus* Santos,1985 from the Aptian/Albian Muribeca Formation in the State of Alagoas, Brasil, a number of other species of *Vinctifer* have been recognised, namely *V. longirostris* Santos, 1990 and *V. araripensis* Santos, 1994 from the Brasilian Aptian Marizal Formation in the Tucano Basin and the Albian Santana Formation in the Araripe Basin respectively. Like *V. comptoni*, these species are quite distinct from the Australian material here referred to the new genus *Richmondichthys*.

A heavily ossified and fused neurocranium from the late Campanian of Patagonia, illustrated by Brito (1997) could relate to either *V. comptoni* or *R. sweeti* but is too incomplete to enable its specific identity to be resolved with any certainty. Predentaries and isolated scales that are much deeper than long are recorded from the Barremian Missao Velha Formation of the Chapada do Araripe and identified as *Vinctifer* by Brito et al.(1994). This material appears to lack close affinity with *Richmondichthys*.

Taverne (1969) referred the partial posterior of a body of an aspidorhynchid from the Cretaceous of Equatorial Guinea to *Belonostomus*; this material has very deep lateral line scales compared with those immediately above and below them, suggesting to Brito (1997) the material is more likely to be referable to *Vinctifer*, supporting a view taken earlier by Maisey (1991). It is unlikely this material is more closely related to *R. sweeti*. Similarly, the specimen from the Jurassic of Antarctica, illustrated by Brito (1997, fig. 28) appears to be more appropriately assigned to *Vinctifer* as suggested by him. It had been identified previously as *Aspidorhynchus* by Richter & Thomson (1989).

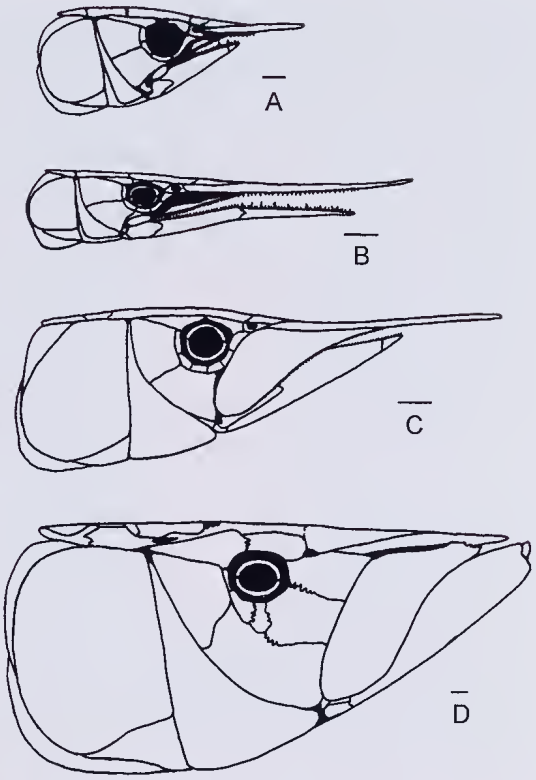

FIG. 11. Comparison of reconstructed heads of aspidorhynchids. A, *Aspidorhynchus* acutirostris (Blainville, 1818); B, *Belonostomus* tenuirostris (Agassiz, 1833); C, *Vinctifer comptoni* (Agassiz, 1841); and D, *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891). A,B and C from Brito (1997). Scale bars = 1cm.

It thus appears that *Richmondichthys* is known only with certainty from the Albian of north central Queensland, Australia. On the other hand, *Vinctifer* probably existed widely throughout Gondwanaland from South America, Africa and Antarctica but, as yet, has not been recorded from Australia.

Day et al. (1983) indicate that, during the Albian, deposition in the northern part of the Eromanga Basin in central Queensland took place in restricted marine and lagoonal environments, with limited communication with the sea in the Carpentaria Basin to the north. The northern

seaway reestablished across the Euroka Arch in late Albian times and was marked by the deposition of the interbedded black shale and limestone of the Toolebuc Formation. Oil shale deposits of this formation indicate specialised environmental conditions which favoured the growth and preservation of organic remains. These conditions were terminated by continued transgression and the succeeding Allaru Mudstone represents normal marine deposition. Sedimentation in the Eromanga Basin ended with the regressive cycle in late Albian time as the sea withdrew into the Carpentaria Basin.

Richmondichthys was well equipped through the defensive nature of its heavily armoured scales and dermal bones to co-exist with a range of predatory reptilian, teleost and selachian contemporaries. Lack of teeth and the weight of the skeletal elements point to an incapacity to move quickly either to capture food or to escape predators. The organisation of the cheek bones and their 'hinging' along the length of the neurocranium, together with the extreme length of the gill rakers support the view that *R. sweeti* was a filter feeder, either gulping to ingest food or widely opening its jaws and ballooning its cheeks whilst moving slowly through plankton swarms. Large specimens predominate amongst those preserved and the species was one of the most common in Queensland's Lower Cretaceous.

ACKNOWLEDGEMENTS

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LITERATURE CITED

AGASSIZ, L. 1833-44. Recherchessur les Poissons fossiles. Neuchatel. 5 vols. 1420 pp., with supplement.

BRITO, P.M. 1992. L'endocrane et le moulage endocranien de *Vinctifer comptoni* (Actinoptrtygii, Aspidorhynchiformes) du Cretace inferieur du Bresil. Annals of Paleontology (Vertebrate - Invertebrate) 78(3): 129-57.

1997. Revision des Aspidorhynchidae (Pisces, Actinopterygii) du Mesozoique: osteologie, relations phylogenetiques, donnces environmentaleset biogeographiques. Geodiversitas 19(4): 681-772.

DAY, R.W., WHITAKER, W.G., MURRAY, C.G., WILSON, I.H. & GRIMES, K.G. 1983. Queensland geology – a companion volume to the 1:250000 scale geological map (1975). Publications of the Geological Survey of Queensland 383: 1-194.

ETHERIDGE, R. 1872. Description of Palaeozoic and Mesozoic fossils of Queensland. Quarterly Journal of the Geological Society of London 28: 317.

ETHERIDGE, R. JNR & SMITH WOODWARD, A. 1891. On the occurrence of the genus *Belonostomus* in the Rolling Downs Formation (Cretaceous) of Central Queensland. Transactions of the Royal Society of Victoria 2(2): 1-7.

JACK, R.L. & ETHERIDGE, R. JNR 1892. The geology and palaeontology of Queensland and New Guinea. Publications of the Geological Survey of Queensland 92(1): 504.

JORDAN, D.S. 1919. New genera of fossil fishes from Brazil. Proceedings of the Academy of Natural Science of Philladelphia 71: 208-10.

1921. Piexes cretaceos do Ceara e Piauhy. Monografias. Servico Geologico e Mineralogico do Brasil 3: 101.

MAISEY, J.G. 1991. *Vinctifer.* Pp 170-89. In Maisey, J.G. (ed.) Santana Fossils. (TFP: New York).

NICHOLSON, H.A. & LYDEKKER, R. 1889. A manual of palaeontology. Edit. 2. (Edinburgh and London).

PATTERSON, C. 1973. Interrelationships of holosteans. Pp 233-305. In Greenwood, P.M., Wiles, R.S. & Patterson, C. (eds) Interrelationships of fishes. (Academic Press: London).

RICHTER, M. & THOMSON, MRA. 1989. First Aspidorhynchidae (Pisces: *Teleostei*) from Antarctica. Antarctic Science 1(1): 57-64.

SANTOS, R. da S. 1985. Sobre a presenca de *Vinctifer* Jordan (Pisces, Aspidorhynchidiformes) na Formacao Muribeca, Estada de Algoas. Pp. 47-50. In Coletania de trabelhos paleontologicos. (Departmento Nacional da Prodção Mineral: Brasilia).

1990. *Vinctifer longirostris*, do Cretaceo inferior da formacao Marizal, Estata da Bahia, Brasil. Anais de Academia Brasileira de Ciencias 62 (3): 251-60.

1994. *Vinctifer araripensis* sp. nov. da Formacao Santana. Bacia do Araripe, NE do Brasil. Anais de Academia Brasileira de Ciencias 66(1): 85-94.

TAVERNE, L. 1969. Sur la presence d'un Aspidorhynchidae (Pisces Holosteen, Order Aspidorhynchidiformes) dans les terrains eocretaciques de la Guinee Equatoriale. Revue de zoologie et de botanique africaines 79(3/4): 261-4.

WESTOLL, T.S., 1944. The Haplolepidae, a new family of late Carboniferous bony fishes. Bulletin of the American Museum of Natural History 83: 1-34.

FOUR NEW GENERA OF MONOGENEA (DACTYLOGYRIDAE) FROM THE GILLS OF AUSTRALIAN ATHERINIFORM FRESHWATER FISHES

DAVID CORLIS

Corlis, D. 2004 06 30: Four new genera of Monogenea (Dactylogyridae) from the gills of Australian atheriniform freshwater fishes. *Memoirs of the Queensland Museum* **49**(2): 537-571. Brisbane. ISSN 0079-8835.

To date only 26 monogenean parasite species have been described from Australian freshwater fishes. In this study freshwater fishes of the Atheriniformes, represented in Australia by the Melanotaeniidae, Atherinidae and Pseudomugilidae, were examined for monogenean gill parasites. Nineteen new dactylogyrid monogeneans are described; *Longidigitis auripontiformis* gen. et sp. nov., *L. robustus* sp. nov., *Iliocirrus iliocirrus* gen. et sp. nov., *Helicirrus splendidae* gen. et sp. nov. and *H. megaloanchor* sp. nov. from *Melanotaenia splendida splendida* (Peters, 1876); *L. gracilis* sp. nov. from *M. utcheensis* McGuigan, 2001; *I. nazlini* sp. nov. from *M. eachamensis*; *L. maccullochii* sp. nov. and *H. maccullochii* sp. nov. from *M. maccullochi* Ogilby, 1915; *I. trifasciatae* sp. nov., *H. meivori* sp. nov. and *L. hopevalensis* sp. nov. from *M. trifasciata* (Rendahl, 1922); *I. ornatusi* sp. nov. from *Rhadinocentrus ornatus* Regan, 1914; *L. utcheei* sp. nov. from *Cairnsichthys rhombosomoides* (Nichols & Raven, 1928); *Recurvatus chelatus* gen. et sp. nov. and *I. rossi* sp. nov. from *Craterocephalus stercusmuscarum stercusmuscarum* (Günther, 1867); *H. marjoriaea* sp. nov. from *Craterocephalus marjoriae* Whitley, 1948; *R. signiferi* sp. nov. from *Pseudomugil signifer* Kner, 1865; and *H. gertrudaea* sp. nov. from *Pseudomugil gertrudae* Weber, 1911. *Longidigitis*, *Iliocirrus*, *Helicirrus* and *Recurvatus* are defined by copulatory apparatus morphology of which 4 types are recognised. Species are recognised on morphological and morphometric variation of haptoral sclerites as well as copulatory apparatus morphology. Multivariate analysis of variance, principal component analysis and discriminant function analysis of morphometric variation are used to assess congruence of genera and species initially distinguished by morphology. Multivariate analysis identified significant differences ($p<0.01$) between species within each genus for 24 measured haptoral sclerite characters. Principal component analysis corroborated the species recognised by morphology, and discriminant function analysis identified morphometric characters that can best identify genera and species. Discriminant function analysis cross-validation classified 97.1% of the 591 measured parasites into their correct genus, and 99.5% were classified correctly into their respective species based on haptoral sclerite morphometric variation alone. ❐ *Melanotaeniidae, Atherinidae, Pseudomugilidae, Monogenea, rainbowfish.*

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There have been very few studies of monogenean parasites from Australian freshwater fishes. Johnston & Tiegs (1922) described 13 species in 6 genera. Since then 9 publications have described Australian freshwater Monogenea (Fletcher & Whittington, 1998). To date 26 species of monogenea have been described from 16 species of native freshwater fishes (Fletcher & Whittington, 1998). With approximately 300 species of freshwater fish known in Australia (Allen et al., 2002), much work remains.

The Atheriniformes comprises 6 families, 49 genera, and approximately 285 species (Dyer & Chernoff, 1996) and its members are found in marine and freshwater environments from tropical and temperate regions. In Australia and New Guinea, Atheriniformes is represented by Melanotaeniidae, Pseudomugilidae and Atherinidae (Allen, 2002). The former 2 are endemic (Dyer & Chernhoff, 1996). Melanotaeniidae includes 69 described species in 7 genera (Allen & Renyaan, 1998; McGuigan, 2001). Of these the Australian mainland has 4 genera with 16 species (McGuigan, 2001). Outside Australia, 5 Atheriniformes, *Hypoatherina temminckii* (Bleeker, 1853), *H. valenciennei* (Bleeker, 1853) (= syn. *Atherina. bleekeri*), *Atherina araea* (Jordan & Gilbert, 1882), *A. stipes* (Müller & Troschel, 1848), *Atherinomorus lacunosus* (Forster, 1801), all marine, have been examined for monogenean parasites. Eight species of dactylogyrid Monogenea, *Diversohamulus tricuspidatus* Bychowsky & Nagibina, 1969, *D. curvionchus*, Zhukov, 1984, *Atherinicus cornutus*

Bychowsky & Nagibina, 1969, *A. subserratus* Zhang et al., 2001, *A. bychowskyi* Zhukov, 1984, *A. cubanus* Zhukov, 1984, *Ancyrocephalus atherinae* Priee, 1934 and *Ancyrocephalus littoralis* Paperna & Kohn, 1964 are known from these hosts. Deseriptions of monogenean parasites from atheriniform fishes from freshwater or from Australia are lacking.

Two sets of morphological charaeters are often applied to define genera of Dactylogyridae. Bychowsky & Nagibina, (1978) considered the following morphological characteristics important in separating genera: 1) structure of the eentral and haptoral hooks; 2) number of chitinous elements in the haptoral armature; 3) position of the testis in relation to the ovary; 4) confluence or non-confluence of distal end of intestinal tract; 5) situation of vas deferens in relation to intestine; and 6) placement of the vaginal pore. These characters have been the main basis for many taxonomic groupings of dactylogyrid mongeneans.

Secondly, eopulatory apparatus structure which was not eonsidered important by Bychowsky & Nagibina (1978), is having a greater role in defining genera than previously. It was recognised early in monogenean taxonomy that diagnostically important sexual characters have more taxonomie value than the sporadic occurrence of spines on, or differenees in size or shape of certain haptoral parts (e.g. Mizelle & Hughes, 1938). Young, (1968) recognised the importance of minor variations in copulatory apparatus morphology and used these to group speeies of *Haliotrema*. However, he did not go as far as to separate these groups into different genera. The reclassification of the Nearctic genera of Daetylogyridae used minor variations in copulatory apparatus morphology and identified several types (Beverley-Burton & Suriano, 1980a, b; Suriano & Beverley-Burton, 1982; Beverley-Burton & Klassen, 1990). More recently, copulatory apparatus morphology has been used to classify the groups of *Haliotrema* species from the marine boxfish (Klassen, 1991).

Haptoral, rather than copulatory apparatus, characters tend to be used for defining species. Generally, haptoral characters are more easily identified. However, when morphological characters among different species are not easily distinguished, a statistical approach can be used on the morphometrie variation of the characters. Analytical tools such as discriminant function analysis (DFA), principal component analysis (PCA) and multivariate analysis (MANOVA) are used to distinguish species and genera. Such methods have been little used in studies of monogenean species. Klassen (1991) used MANOVA and DFA to define species of *Haliotrema* from boxfish while MANOVA and PCA were used to identify species of *Gyrodactylus* from salmonid hosts (Shinn et al., 2000).

TABLE 1. Host species examined and collection sites.

host	location	longitude	latitude
C. marjoriae	Amamoor Ck	152°40'E	26°21'S
C. rhombosomoides	Utchee Ck	145°56'E	17°37'S
C. rhombosomoides	Behana Ck	145°56'E	17°17'S
C. s. stercusmuscarum	Tungamull Ck.	150°30'E	23°30'S
C. s. stercusmuscarum	Ross R.	146°45'E	19°18'S
M. eachamensis	Dirran Ck	145°06'E	17°27'S
M. maccullochi	McIvor R	145°06'E	15°09'S
M. maccullochi	Corduroy Ck	145°50'E	18°10'S
M. s. splendida	Bluewater Ck	146°45'E	19°18'S
M. s. splendida	Stewart Ck.	145°46'E	19°22'S
M. trifasciata	McIvor R	145°06'E	15°09'S
M. trifasciata	Dulhunty R.	142°14'E	11°53'S
M. utcheensis	Utchee Ck	145°56'E	17°37'S
P. gertrudae	Howard Ck.	130°50'E	12°27'S
P. signifer	Liverpool Ck	145°56'E	17°43'S
P. signifer	S. Mossman R.	145°23'E	16°29'S
R. ornatus	Brunswick Ck	151°60'E	28°70'S
R. ornatus	Bible Ck	150°40'E	28°50'S

The first monogenean parasites from Melanotaeniidae, Atherinidae and Pseudomugilidae from Australian freshwater systems are described and comparison and use of the two approaches to genus-level classification is discussed. An applied statistical approach, using MANOVA, PCA and DFA, will eonfirm or refute a correlation between haptoral sclerite variation and the genus- and species-level classification based on morphology.

MATERIALS AND METHODS

Identification of hosts is according to Allen (2002) and McGuigan (2001). Host specimens (Table 1), collected by a number of methods (6mm seine net, dip net), were killed by placing them in iced water for thirty seconds. This kills the host but not the monogeneans. The gills were removed from the host using fine needle forceps and placed in a 50mm Petri-dish containing water from the collection site. Monogenean parasites were observed with a ×40 dissecting microscope and removed from the gills using a fine needle. Live parasites were transferred to a 50× 25mm glass slide using a pipette and covered with a cover slip. Examination of live parasites used ×400 and × 1000, D.I.C. Nomarski optics to determine internal soft tissue morphology. As the slides dried, specimens became compressed which caused body fluids to be exuded. This leaves an outline of the worm's tissue edges

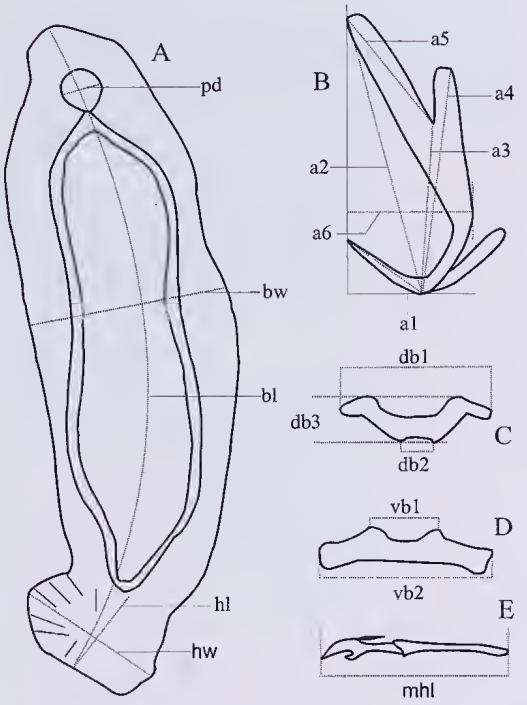

FIG. 1. Parasite measurements. A. Body measurements: bl, body length; bw, body width; hl, haptor length; hw, haptor width; pd, pharynx dia. B. Anchor measurements a 1-5. C. Dorsal bar measurements db1-3. D. Ventral bar, vb1-2. E. Hook length, hl 1-7. Numbers 1-7, hook numbering system.

showing details of all sclerotised morphometric characters and most of the morphological characters. The worms were preserved in this state in glycerol-ammonium-picrate (Malmberg, 1970) by placing a drop at the edge of the cover slip and allowing capillary action to spread the preservative under the cover slip. Nail polish was used to seal the cover slip. This is referred to as technique one. When live specimens could not be examined, gills were preserved in 5% formalin, parasites were extracted and mounted in Grey & Weiss mountant (Humason, 1979) or glycerol-ammonium picrate. This is referred to as technique two. Holotype and paratypes of each species are deposited at the Queensland Museum.

Morphometric variables of 5 soft body and 24 sclerotised variables of the haptoral apparatus were measured (Fig. 1). Where possible, at least 20 parasites of each species were measured. Hook numbering follows that of Mizelle, (1936) (Fig. 2A, B). The haptoral terminology follows Gussev, (1973) and male copulatory apparatus terminology follows Klassen, (1991).

STATISTICAL ANALYSIS. Data were analysed using SPSS for Windows 11 (SPSS Inc.). Descriptive statistics were obtained for the soft body and the haptoral sclerite variables. Formalin preserved specimens were used for measurements as more specimens were available in this state. Means and range are expressed for soft body measurements and means and one standard error are expressed for sclerite variables. Soft body data were not examined further as variation is commonly related to preservation techniques (Klassen, 1991). Examination of sclerite variables used multivariate analysis of variance (MANOVA), principle component analysis (PCA) and discriminant function analysis (DFA). Initial examination of the data for normality and homoscedasticity, graphically using frequency distributions and statistically using Levene's test (with $\propto=0.01$), indicated a need for transformation. Data for MANOVA were natural-log transformed ($\ln(1+x)$), while data for PCA and DFA were z-score transformed to approximate multivariate normality, homoscedasticity and to remove the scale factor between variables. Each genus was examined for mean differences in variables between species using MANOVA. Tests were considered significant at the experiment-wise error rate $\propto=0.01$. A post-hoc analysis (MANOVA) for pair-wise comparisons and range used the Scheffé test. The significance level of the Scheffé test ($\propto=0.01$) is designed to allow all possible linear combinations of group means to be tested, not just pair-wise comparisons. The result is that the Scheffé test is often more conservative than other tests. Tukey's HSD test (unequal group sizes present) was also conducted and results compared with Scheffé test as unequal group sizes were present in the data. The Tukey's HSD test uses a Bayesian approach and uses the harmonic mean of the sample size when the sample sizes are unequal.

For PCA the covariance matrix was used and initially all characters were entered in analyses. Characters were removed from the final set of analyses based on low communality (<0.7). Data were examined at two levels. Firstly, all species together; secondly, each genus was examined separately. Visual examination of scatter plots assessed if separation of parasite species occurred.

Discriminant function analysis identified morphometric sclerite characters having highest correlation with genera and species, recognised

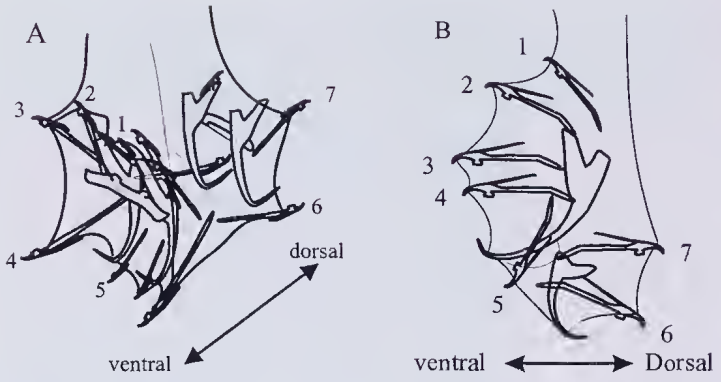

FIG. 2. A, haptoral sclerite relationships and orientation for *Longidigitis*, *Iliocirrus*, *Recurvatus*, and *Helicirrus*: *H. marjoriaea*, *H. mcivori* and *H. gertrudaea* species. 1-7, hook numbering. B, for *H. megaloanchor*, *H. splendidae* and *H. maccullochii*.

by morphology. The analysis used the stepwise approach and the within-group covariance distance matrix (Mahalanobis distances). Probability of F to enter and F to remove were set at ($P<0.01$) and ($P<0.05$) respectively. The stepwise method removes uninformative characters from analysis based on the significance levels set. A cross-validation (leave one out classification) assessed the validity of the genera and species, and groups were weighted by sample size. Analyses were conducted at two levels. Firstly, examination of all species together; secondly, each genus was examined separately. Scatter plots were examined to determine if separation of parasite species occurred using the first three functions.

SYSTEMATICS

Order MONOGENOIDEA Bychowsky, 1937
Superfamily DACTYLOGYRIDEA Bychowsky, 1937
Family DACTYLOGYRIDAE Bychowsky, 1933
Subfamily ANCYROCEPHALINAE Bychowsky, 1937

Recurvatus gen. nov.

TYPE-SPECIES AND HOST. *Recurvatus chelatus* sp. nov. from *Craterocephalus stercusmuscarum stercusmuscarum* (Günther, 1876), Ross River, Qld (19°18'S, 146°45'E).

ETYMOLOGY. Latin *re-* back and *curvatus* curved; refers to the copulum shaft shape.

DIAGNOSIS. Body minute (rarely >150µm), divisible into cephalic, trunk, peduncle and haptoral regions. Tegument thin, smooth. Head organs 3 pairs; cephalic lobes, glands present. Eyes rarely 2 pairs, commonly 1 pair, anterior or dorsal to pharynx, when present posterior pair larger than anterior pair, generally compact; granules large, subspherical. Mouth subterminal, midventral; pharynx muscular; intestine bifurcate, caeca united posterior to gonads; diverticula absent. Vitellaria coextensive with intestine, lateral and posterior to crura. Gonads intercaecal; ovary trianguloid, in middle part of body; testis, single, oval to elliptical, smaller than ovary, overlapping ovary dorsally. Vas deferens originating from anterior end of testis, looping around left intestinal crus, joining copulum base dextrally; seminal vesicle formed by dilation of vas deferens, non-sclerotised; prostatic reservoir single, terminating on right side of copulum base. Copulatory apparatus sclerotised, its shaft originating from anterior end of copulum base, consisting of a counter clockwise ring circling copulum base (ventral view, see Kritsky et al., 1985); copulum base bulbate; accessory piece present; spiral filament absent (Type I copulatory apparatus Fig. 26A). Vagina sclerotised or not, aperture sclerotised, sinistroventral; seminal receptacle, median, formed by dilation at distal end of vagina, anterior to ovary. Egg with polar filament. Haptor well set off from body, wider than body, subhexagonal. Anchors two pairs, opposed dorsoventrally (Fig. 2A), well-developed inner, outer roots, dorsal pair smaller than ventral pair; shaft, blade present; point well-developed; wing processes present. Transverse bars 2, not articulated; ventral bar arcuate with 2 knobs directed anteriorly 1/3 of length from end; dorsal bar arcuate, often transversely elongate with lateral extensions. Hooks 14, 6 pairs (H2-H7) marginal, 1 pair (H1) more central, 5 pairs ventral (H1-5), 2 pairs dorsal (H6-7), hook H4 longer than anchors; hook shaft and handle equally prominent, handle with expanded demarcation; hook H7 anterior to dorsal anchors. Parasites of freshwater atheriniform fishes.

OTHER SPECIES. *R. signiferi* sp. nov. from *Pseudomugil signifer* Kner, 1865.

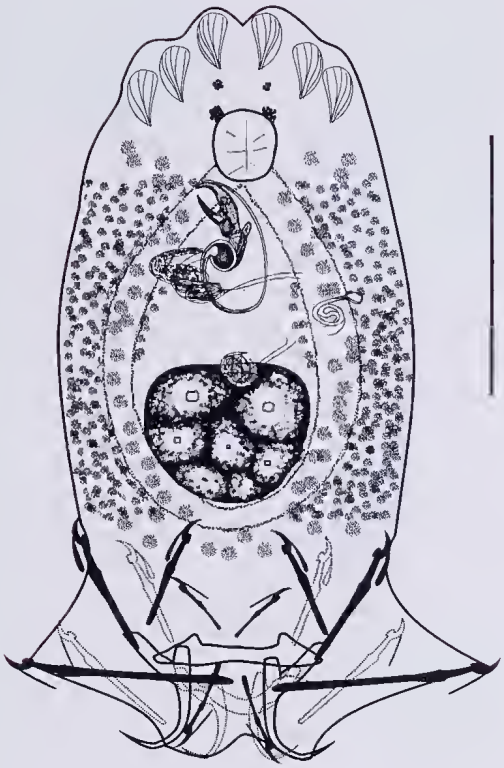

FIG. 3. *Recurvatus chelatus* sp. nov.; composite drawing whole worm, ventral. Scalebar 50µm.

Recurvatus chelatus sp. nov.
(Figs 3-4, Table 2)

MATERIAL. HOLOTYPE. QMG219478 and PARATYPES. QMG219479-219482. All from *Craterocephalus stercusmuscarum stercusmuscarum*, Ross River, Qld, (19°18'S, 146°45'E).

ETYMOLOGY. Latin *chela*, claw; referring to shape of the copulatory apparatus accessory piece.

DESCRIPTION. Eyes 2 pairs, anterior or dorsal to pharynx, anterior eyes usually comprising a few dispersed granules. Anchors with well-developed recurved points. Ventral bar inverted V. Dorsal bar slightly smaller than ventral, in form of deep inverted arch, lateral extensions present. Hooks increase in length from H1 to H4, H2 and H7 of similar size, H3 and H6 of similar size, all similar thickness. Copulatory apparatus well developed; copulum shaft thin; accessory piece large, well sclerotised, chelate. Vagina sclerotised along entire length, consisting of double coil.

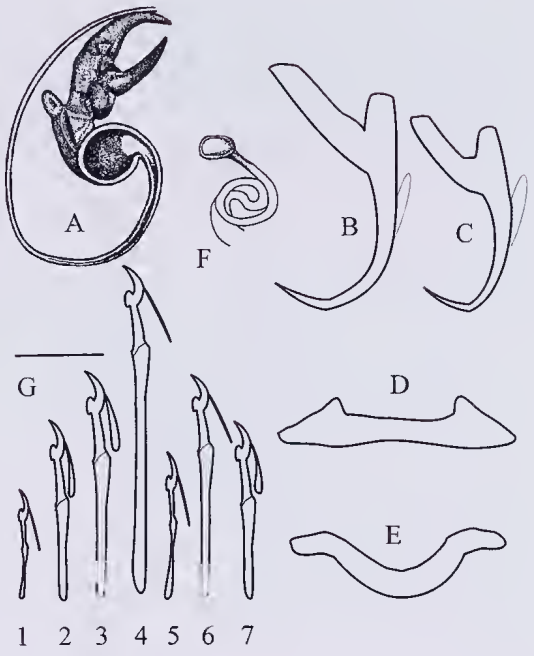

FIG. 4. *Recurvatus chelatus* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, vagina; G, hooks 1-7. Scalebar 10µm.

REMARKS. This species is easily distinguished from *R. signiferi* sp. nov. by the enlarged chelate accessory piece and a coiled sclerotised vagina.

Recurvatus signiferi sp. nov.
(Fig. 5, Table 2)

MATERIAL. HOLOTYPE. QMG218862 and PARATYPES. QMG218863-218866. All from *Pseudomugil signifer*, Liverpool Creek, Qld, (17°43'S, 145°56'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes 2 pairs, anterior or dorsal to pharynx. Copulatory apparatus reduced, shaft thin; accessory piece reduced, lightly sclerotised, thumb-shaped, partially encapsulating distal end of copulum shaft. Vagina nonsclerotised, tapered, straight. Anchors with well-developed recurved points; dorsal anchor slightly smaller than ventral. Ventral bar inverted V. Dorsal bar slightly smaller than ventral bar, consisting of a deep inverted arch with lateral extensions. Hooks H2 and H7 of similar size, H3 smaller than H2, H4 handle much thinner than other hooks, H6 smaller than H3.

TABLE 2. Morphometric measurements (μm) of *Recurvatus* species. Means and standard error. ME, number of parasites measured; BL, body length; BW, body width; HW, haptor width; HL, haptor length; PD, pharynx diameter; DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. ( ) range.

	R. chelatus	*R. signiferi*
ME	28	40
BL	(100-155)	(100-150)
BW	(45-80)	(50-70)
HL	(25-50)	(30-50)
HW	(60-85)	(55-90)
PD	(9-11)	(10-12)
DA1	6.6 ± 0.14	6.8 ± 0.12
DA2	22.9 ± 0.29	22.4 ± 0.24
DA3	17.4 ± 0.24	15.1 ± 0.20
DA4	21.3 ± 0.27	18.6 ± 0.23
DA5	7.7 ± 0.21	8.4 ± 0.18
DA6	10.8 ± 0.22	9.6 ± 0.18
VA1	5.7 ± 0.14	5.0 ± 0.12
VA2	27.5 ± 0.33	27.4 ± 0.28
VA3	20.2 ± 0.26	19.2 ± 0.22
VA4	24.9 ± 0.34	23.4 ± 0.28
VA5	11.6 ± 0.28	12.5 ± 0.23
VA6	13.7 ± 0.26	13.4 ± 0.21
DB1	24.2 ± 0.31	22.4 ± 0.26
DB2	0	0
DB3	7.8 ± 0.15	6.3 ± 0.13
VB1	27.4 ± 0.32	23.9 ± 0.27
VB2	13.2 ± 0.20	12.1 ± 0.17
H1	12.4 ± 0.20	13.5 ± 0.17
H2	20.2 ± 0.30	30.2 ± 0.25
H3	25.0 ± 0.40	27.5 ± 0.34
H4	36.7 ± 0.42	43.6 ± 0.35
H5	16.6 ± 0.22	15.2 ± 0.18
H6	24.0 ± 0.35	25.9 ± 0.29
H7	19.7 ± 0.32	29.0 ± 0.17

Helicirrus gen. nov.

TYPE SPECIES. *Helicirrus splendidae* sp. nov. from *Melanotaenia splendida splendida*, Ross River, Qld, (19°18'S, 146°45'E).

ETYMOLOGY. Latin *heli-*, coiled and *cirrus*, hair; referring to the distal end of copulum shaft.

DIAGNOSIS. Body minute (rarely >150μm), divisible into cephalic, trunk, peduncle, haptoral regions. Tegument thin, smooth. Head organs 3 pairs; cephalic lobes, glands present. Eyes 1or 2 pairs, anterior or dorsal to pharynx, anterior eyes smaller. Mouth subterminal, midventral; pharynx muscular; intestine bifurcate, united posterior to gonads. Gonads intercaecal; ovary ovoid to elliptical, in posterior part of body; testis, single, oval to elliptical, smaller than ovary, overlapping ovary dorsally. Vas deferens originating from anterior end of testis, looping left intestinal crus; seminal vesicle formed by expansion of vas deferens. Copulatory apparatus consisting of a

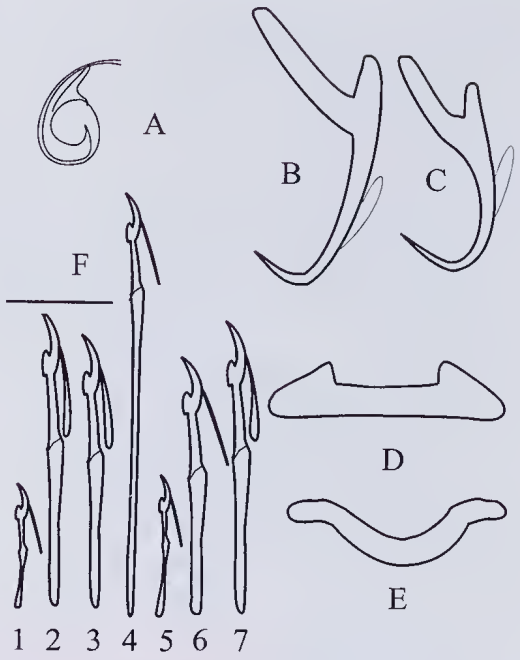

FIG. 5. *Recurvatus signiferi* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

bulbate copulum base; shaft emanating from anterior end of base and recurved sinistro-posteriorly, highly coiled at posterior end with coils posterior to copulum base just anterior to gonads; accessory piece thin elongated spike, attached to right side of base; hair-like filament originating at anterior extremity of shaft (Type II copulatory apparatus, Fig. 25B). Single prostatic reservoir often partially sclerotised. Vagina not observed; seminal receptacle anterior to ovary. Haptor well set off from body, round to hexagonal, equal to body width. Anchors 2 pairs, 1 dorsal, 1 ventral, opposed dorsoventrally (elongated hook haptor form Fig. 2A) or dorsal anchor posterior to ventral anchors (reduced hook haptor form Fig. 2B); ventral anchors larger than dorsal; inner, outer roots distinct; shaft, blade present; wing processes inconspicuous. Two transverse bars not articulated; ventral bar straight, transversely elongate, often much larger than dorsal, with 2 processes 1/3 of length from ends along anterior edge, directed anteriorly. Dorsal bar arched, well-developed or highly reduced. Hooks 14, 6 pairs marginal (H2-H7), pair 1 more central, 5 pairs (H1-5) ventral, 2 pairs dorsal (H6-7); reduced form with kink 1/3 of

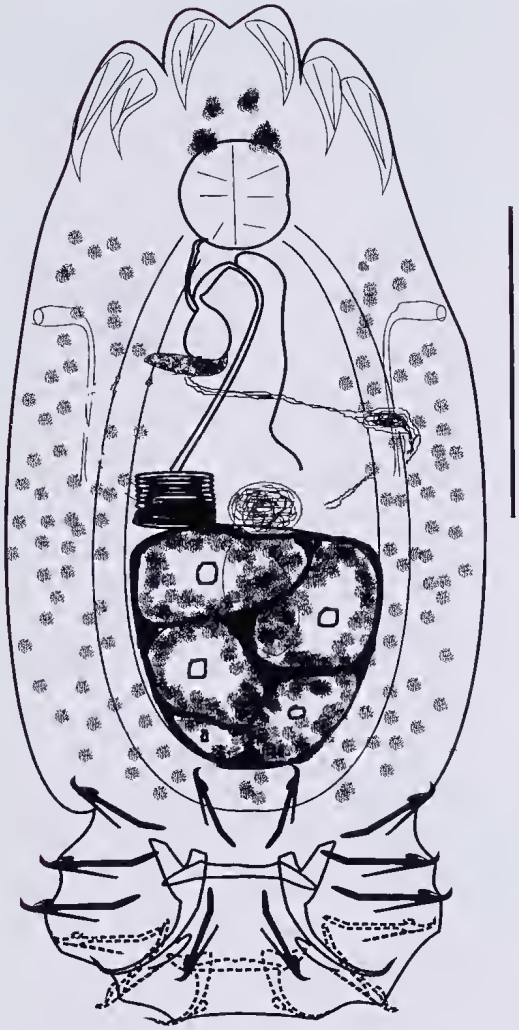

FIG. 6. *Helicirrus splendidae* sp. nov.; composite drawing whole worm, ventral. Scalebar 50μm.

length from end of handle, H7 posterior to ventral anchors, H4 shorter than ventral anchor; elongated form with H4 longer than ventral anchor, H7 anterior to ventral anchors; hook shaft and handle equally prominent, with prominent expanded demarcation; wing processes present. Parasites on gills of freshwater atheriniform fishes.

OTHER SPECIES. *H. megaloanchor* sp. nov. from *M. s. splendida* (Peters, 1866), *H. mcivori* sp. nov. from *M. trifasciata* (Rendahl, 1922), *H. maccullochii* sp. nov. from *M. maccullochi* Ogilby, 1915, *H. marjoriaea* sp. nov. from *C. marjoriae.*

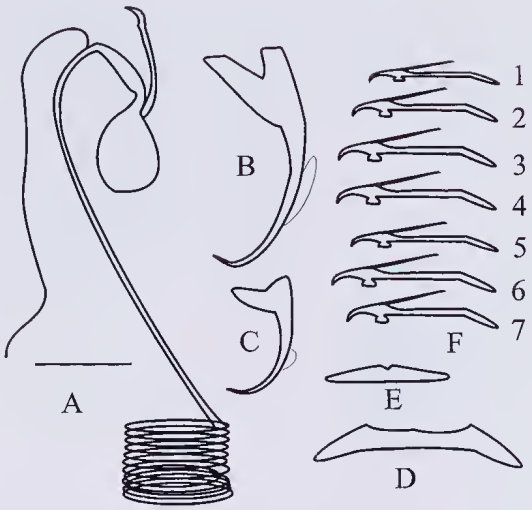

FIG. 7. *Helicirrus splendidae* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7; Scalebar 10μm.

Helicirrus splendidae sp. nov.
(Figs 6-7, Table3)

MATERIAL. HOLOTYPE QMG218850 and PARATYPES QMG218851-218854. All from *Melanotaenia splendida splendida*, Ross River, Qld, (19°18'S, 146°45'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes two pairs, anterior eyes slightly smaller. Haptor with reduced hook orientation (Fig. 2B). Dorsal anchors smaller than ventral, with well-developed inner, reduced outer root; point poorly developed. Ventral anchors with well-developed inner root, reduced outer root; recurved point poorly developed. Dorsal bar much smaller than ventral, inverted arch, thin, weakly developed. Hooks of reduced form and similar size. Copulum shaft with approximately ten coils at posterior end; copulum base single chamber, bulbate, slightly elongate. Accessory piece slightly curved. Seminal vesicle formed by kidney shaped expansion of vas deferens midway between copulum base and loop of intestine. Two excretory pores with cup shaped cavity at body margin, opening at level of copulatory apparatus, ducts extending posteriorly along margin of intestine.

REMARKS. This species is similar to *H. maccullochii* sp. nov. by having reduced hooks, dorsal anchors and bar. They differ in the shape of

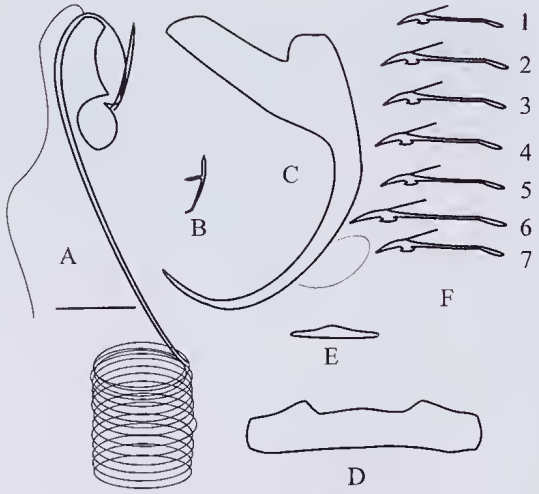

FIG. 8. *Helicirrus megaloanchor* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, dorsal anchor; C, ventral anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

the copulum shaft and ventral anchor inner root length.

Helicirrus megaloanchor sp. nov.
(Fig. 8, Table 3)

MATERIAL. HOLOTYPE QM G219458 and PARATYPES QM G219459-219462. All from *Melanotaenia splendida splendida*, Ross River, Qld, (19°18'S 146°45'E).

ETYMOLOGY. Named after the large size of the ventral anchors.

DESCRIPTION. Eyes two pairs. Haptor with reduced hook sclerite orientation (Fig. 2B). Ventral anchors much larger than dorsal, well-developed inner, reduced outer root; recurved point well-developed. Dorsal anchors with weakly developed inner, outer root, inner root directed toward point; point reduced or absent, often inconspicuous. Dorsal bar slight inverted arch, thin, highly reduced, often inconspicuous, smaller than ventral. Hooks of reduced form and similar size. Copulum shaft expanded proximally posterior to shaft recurve loop, approximately 15 coils at posterior end. Accessory piece thin, directed anteriorly, slightly curved tip. Prostatic reservoir partially sclerotised.

REMARKS. This species is similar to *H. splendidae* sp. nov. and *H. maccullochii* sp. nov. by having reduced hooks, dorsal bar and dorsal anchors. They differ in the size of the ventral anchors.

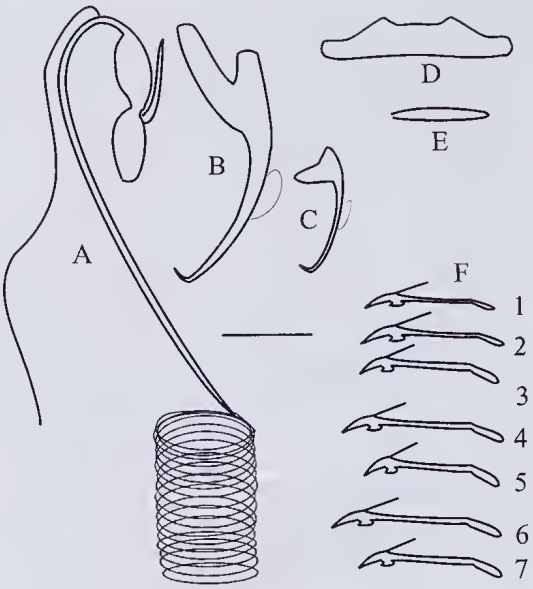

FIG. 9. *Helicirrus maccullochii* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

Helicirrus maccullochii sp. nov.
(Fig. 9, Table 3)

MATERIAL. HOLOTYPE QM G218823 and PARATYPES QM G218824-218827. All from *Melanotaenia maccullochi*, McIvor River, Qld, (15°03'S 145°26'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes one pair. Haptor with reduced hook sclerite orientation (Fig. 2B). Ventral anchors slightly larger than dorsal, well-developed inner, outer roots; recurved point well-developed. Dorsal bar weakly-developed inverted arch, much smaller than ventral. Hooks of reduced form and similar size. Copulum shaft expanded proximally posterior to shaft recurve loop, approximately 35 coils at posterior end; accessory piece thin spike. Prostatic reservoir partially sclerotised.

REMARKS. See remarks for *H. megaloanchor* sp. nov. and *H. splendidae* sp. nov.

Helicirrus mcivori sp. nov.
(Fig. 10, Table 3)

MATERIAL. HOLOTYPE QM G219486 and PARATYPES QM G219487-219489. All from *Melanotaenia trifasciata*, McIvor River, Qld, (15°09'S 145°26'E).

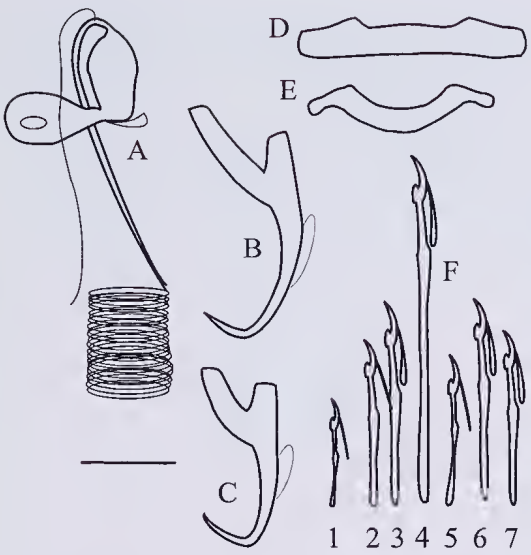

FIG. 10. *Helicirrus mcivori* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Salebar 10μm.

ETYMOLOGY. Named after the type host location.

DESCRIPTION. Eyes one pair. Haptor with elongated hook sclerite orientation (Fig. 2A). Ventral anchors slightly larger than dorsal, well-developed inner, outer roots; recurved point well-developed. Dorsal bar well-developed inverted arch, similar in size to ventral. Hooks elongated form, increasing in handle length from H1 to H4, H4 much longer than other hooks and ventral anchors, H3 and H6 of similar length, H7 anterior to ventral anchors. Copulum base orientated perpendicular and sinistral to shaft; shaft expanded proximal to recurve, approximately 30 coils at posterior end; accessory piece reduced. Seminal vesicle expanded bulb at loop of gut crura.

REMARKS. This species is similar to *H. gertrudaea* sp. nov. and *H. marjoriaea* sp. nov. by having elongated hooks and well-developed dorsal anchors and bar. It differs by having a proximal expansion of the copulum shaft.

Helicirrus gertrudaea sp. nov.
(Fig. 11, Table 3)

MATERIAL. HOLOTYPE QM G218857 and PARATYPES QM G218858-218861. All from *Pseudomugil gertrudaea*, Howard Creek, Northern Territory, (12°27'S 130°50'E).

ETYMOLOGY. Named after the type host.

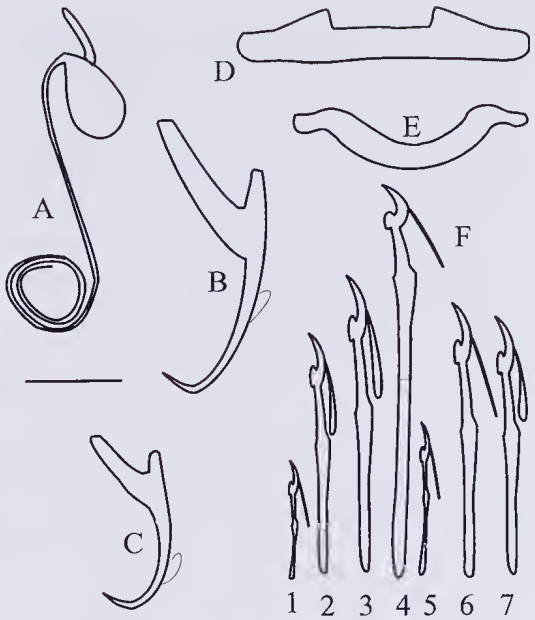

FIG. 11. *Helicirrus gertrudaea* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

DESCRIPTION. Eyes two pairs, anterior eyes reduced. Haptor with elongated hook sclerite orientation (Fig. 2A). Ventral anchors larger than dorsal, well-developed inner, outer roots; recurved point. Dorsal bar well-developed inverted arch, similar in size to ventral. Hooks elongated form, increasing in handle length from H1 to H4 then decrease in length, H4 longer than ventral anchor, H3 longer than H6, H7 longer than H2. Copulum shaft thin, proximal expansion absent, approximately ten coils at posterior end; copulum base single chamber, oval, elongated; accessory piece elongated spike.

REMARKS. This species is most similar to *H. marjoriaea* sp. nov. by having elongated hooks and well-developed anchors and bars. They differ in the number of coils present in the copulum shaft.

Helicirrus marjoriaea sp. nov.
(Fig. 12, Table 3)

MATERIAL. HOLOTYPES QM G218834 and PARATYPES QM G218835-218838. All from *Craterocephalus marjoriae*, Amamoor Creek, Qld, (26° 21'S 152°40'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes one pair. Haptor with elongated hook sclerite orientation (Fig. 2A). Ventral anchor slightly larger than dorsal, well-developed inner, outer roots; recurved point well-developed. Dorsal bar well-developed inverted arch, similar in size to ventral. Hooks elongated form, hook H7 slightly smaller than H2, H3 much longer than H6, H4 longer than anchors. Copulum shaft thin, proximal expansion absent, approximately 30 coils at posterior end; accessory piece elongated spike. Prostatic reservoir partially sclerotised.

REMARKS. See remarks for *H. gertrudaea* sp. nov.

Longidigitis gen. nov.

TYPE SPECIES AND HOST. *Longidigitis auripontiformis* sp. nov. from *M. s. splendida*, Bluewater Creek, Qld, (19°18'S 146°45'E).

ETYMOLOGY. Latin *longus*, long and *digitus*, finger; refers to the hooks.

DIAGNOSIS. Body minute (rarely >150μm), divisible into cephalic, trunk, peduncle and haptoral region. Tegument thin, smooth. Head organs three pairs, cephalic lobes and glands present. Eyes rarely two pairs, commonly one, anterior or dorsal to pharynx, anterior eyes, when present, consisting of scattered granules. Mouth subterminal, midventral; pharynx muscular; intestine bifurcate, united posterior to gonads. Vitellaria coextensive with intestine, lateral and posterior to crura. Gonads intercaecal; ovary trianguloid, in middle part of body; testis single, oval to elliptical, smaller than ovary, overlapping ovary dorsally. Vas deferens originating from anterior end of testis, looping intestinal crus sinistrally, joining dextral side of copulum base posteriorly; seminal vesicle formed by dilation of vas deferens, often partially sclerotised; single prostatic reservoir originating from dextral side of copulum base. Copulatory apparatus consisting of a copulum base; copulum shaft originating from anterior end of copulum base consisting of a single sinistral recurved loop (Type III copulatory apparatus, Fig. 26C) distal end arches anterior to copulum base and is directed at right side of body, terminating dextral to copulum base; base bulbate; accessory piece thumb shaped, directed anteriorly; spiral filament absent. Vagina, non-sclerotised, opening sinistromarginal; seminal receptacle formed by dilation of vagina at distal end, anterior to ovary. Egg with polar filament. Haptor well-set off from body, wider than body, subhexagonal in shape.

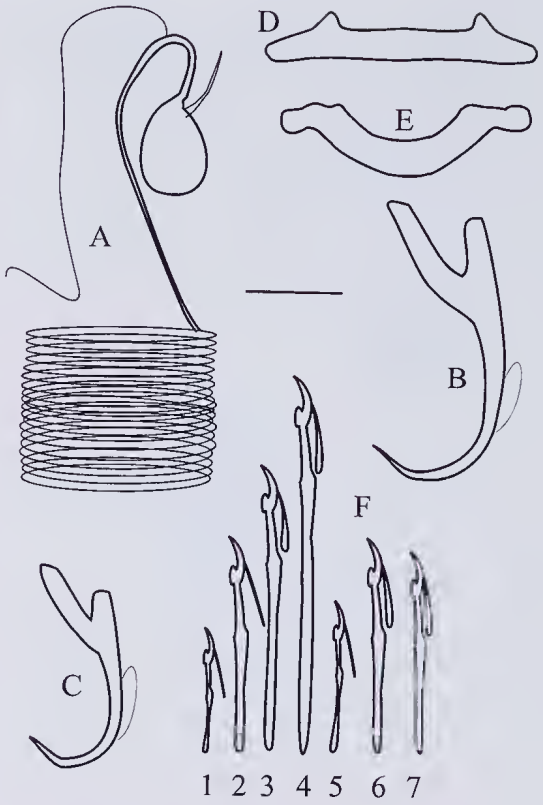

FIG. 12. *Helicirrus marjoriaea* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

Anchors two pairs, well-developed, opposed dorsoventrally (Fig. 2A); dorsal anchors smaller than ventral, inner roots well-developed, outer roots reduced; shaft and blade present; point well developed; ventral anchors inner, outer roots; shaft and blade present; point well-developed. Transverse bars two, not articulated; ventral bar with two knobs directed anteriorly third of length from end, usually tapering laterally, rarely with expansions at ends; dorsal bar arcuate, often transversely elongate with lateral extensions, medial notch present or absent on posterior surface, equal in length or slightly smaller than ventral. Hooks 14, six pairs (H2-H7) marginal, pair one more central, five pairs ventral (H1-H5), two pairs dorsal (H6-7); handle length increases from H1 to H4, H4 always longer than the anchors, H7 anterior to ventral anchors; hook shaft and handle equally prominent, handle with expanded demarcation; wing process present. Parasites of freshwater fish (Atheriniformes).

TABLE 3. Morphometric measurements (μm) of *Helicirrus* species. Means and standard error. ME, number of parasites measured; BL, body length; BW, body width; HW, haptor width; HL, haptor length; PD, pharynx diameter; DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. ( ) range.

	H. splendidae	*H. megaloanchor*	*H. maccullochii*	*H. mcivori*	*H. gertrudaea*	*H. marjoriaea*
ME	28	15	10	17	15	41
BL	(140-200)	(130-170)	(130-200)	(90-160)	(80-100)	(100-150)
BW	(70-140)	(40-80)	(50-90)	(25-50)	(25-40	(50-100)
HL	(25-55)	(35-50)	(25-40)	(25-45)	(20-35)	(25-45)
HW	(50-70)	(50-90)	(50-80)	(40-90)	(50-70)	(60-110)
PD	(15-21)	(10-16)	(17-21)	(7-11)	(8-12)	(9-15)
DA1	2.7 ± 0.17	2.4 ± 0.24	1.80 ± 0.29	4.87 ± 0.26	3.7 ± 0.19	6.07 ± 0.10
DA2	11.3 ± 0.31	9.3 ± 0.47	11.20 ± 0.39	19.4 ± 0.38	18.3 ± 0.32	20.80 ± 0.14
DA3	10.9 ± 0.18	4.7 ± 0.17	12.60 ± 0.31	14.8 ± 0.50	14.2 ± 0.20	15.73 ± 0.12
DA4	12.9 ± 0.26	6.7 ± 0.17	14.10 ± 0.28	17.6 ± 0.68	16.6 ± 0.24	19.43 ± 0.14
DA5	4.2 ± 0.21	2.4 ± 0.18	2.50 ± 0.17	5.1 ± 0.19	7.1 ± 0.28	7.15 ± 0.13
DA6	7.1 ± 0.17	1.9 ± 0.11	5.50 ± 0.22	8.4 ± 0.21	8.6 ± 0.35	10.18 ± 0.16
VA1	2.1 ± 0.16	5.6 ± 0.44	2.10 ± 0.10	4.7 ± 0.17	3.9 ± 0.17	5.78 ± 0.10
VA2	21.6 ± 0.26	38.6 ± 0.44	26.00 ± 0.61	25.6 ± 0.45	27.9 ± 0.34	27.38 ± 0.16
VA3	19.2 ± 0.26	32.0 ± 0.47	23.40 ± 0.45	18.1 ± 0.46	20.4 ± 0.29	21.35 ± 0.13
VA4	22.4 ± 0.26	37.7 ± 0.65	27.40 ± 0.40	21.8 ± 0.48	25.0 ± 0.32	26.30 ± 0.19
VA5	5.9 ± 0.25	13.8 ± 0.52	8.30 ± 0.47	9.8 ± 0.44	11.5 ± 0.27	9.72 ± 0.17
VA6	10.9 ± 0.19	25.6 ± 0.47	13.40 ± 0.40	11.4 ± 0.21	11.9 ± 0.31	13.85 ± 0.14
DB1	12.7 ± 0.33	12.7 ± 0.24	10.50 ± 0.37	19.8 ± 0.32	24.3 ± 0.25	25.68 ± 0.24
DB2	0.00	0.00	.00	0.00	0.00	.00
DB3	2.4 ± 0.13	2.6 ± 0.24	2.30 ± 0.15	5.6 ± 0.18	6.1 ± 0.18	7.50 ± 0.13
VB1	21.9 ± 0.25	31.0 ± 0.58	21.80 ± 0.33	24.5 ± 0.31	24.1 ± 0.35	28.38 ± 0.24
VB2	11.0 ± 0.21	15.3 ± 0.29	7.70 ± 0.30	11.8 ± 0.23	10.9 ± 0.25	15.43 ± 0.22
H1	14.1 ± 0.24	13.9 ± 0.39	13.20 ± 0.42	12.2 ± 0.47	12.2 ± 0.17	13.23 ± 0.17
H2	15.7 ± 0.25	16.9 ± 0.39	16.10 ± 0.23	18.5 ± 0.37	24.5 ± 0.19	22.65 ± 0.18
H3	16.4 ± 0.24	17.1 ± 0.51	16.10 ± 0.23	22.5 ± 0.33	30.3 ± 0.32	30.52 ± 0.29
H4	17.0 ± 0.23	16.2 ± 0.43	16.10 ± 0.18	37.8 ± 0.41	39.3 ± 0.35	41.53 ± 0.28
H5	15.6 ± 0.40	16.6 ± 0.34	13.70 ± 0.37	16.2 ± 0.30	15.9 ± 0.24	17.57 ± 0.19
H6	17.8 ± 0.41	21.1 ± 0.31	17.80 ± 0.39	22.1 ± 0.30	27.5 ± 0.34	22.98 ± 0.23
H7	17.2 ± 0.19	17.1 ± 0.31	16.90 ± 0.43	19.5 ± 0.69	26.8 ± 0.38	21.08 ± 0.19

OTHER SPECIES: *Longidigitis robustus* sp. nov. from *M. s. splendida*, *L. maccullochii* sp. nov. from *M. maccullochi*, *L. hopevalensis* sp. nov. from *M. trifasciata*, *L. gracilis* sp. nov. from *Melanotaenia utcheensis* McGuigan, 2001 and *M. eachamensis*, *L. utcheei* sp. nov. from *Cairnsichthys rhombosomoides* (Nichols & Raven, 1928).

Longidigitis auripontiformis sp. nov.
(Fig. 13-14, Table 4)

MATERIAL. HOLOTYPE QM G218877 and PARATYPES QM G218878-218881. All from *Melanotaenia splendida splendida*, Bluewater Creek, Qld, (19°18'S, 146°45'E).

ETYMOLOGY. Latin *auris*, ear, *pons*, bridge and *forma*, shape; referring to the dorsal bar shape.

DESCRIPTION. Eyes two pairs, rarely one. Dorsal anchors slightly smaller than ventral, with well-developed elongated points, inner roots, slightly reduced outer roots with conspicuous bump on inner curve of shaft; ventral anchor well-developed inner, outer roots. Ventral bar arcuate, not tapering laterally, ends square with protuberance directed anteriorly. Dorsal bar, semi-circular, with lateral extensions, notch absent on posterior edge, thin membranous infill present on anterior edge. Hooks H7 smaller than H2, H6 smaller than H3, H1 and H5 much smaller than H6. Copulum shaft thick; accessory piece well-developed. Vas deferens with partially sclerotised seminal vesicle, extending from copulum to intestinal crus loop. Vagina tubular, usually inconspicuous.

REMARKS. This species is similar to *L. hopevalensis* sp. nov. by having similar shaped anchors and ventral bar. It is distinguished by the thickness of the copulum shaft and the shape of the ventral bar.

Longidigitis hopevalensis sp. nov.
(Fig. 15, Table 4)

MATERIAL. HOLOTYPE QM G219490 and PARATYPES QM G219491-219493. All from *Melanotaenia trifasciata*, McIvor River, Qld, (15°09'S 145°26'E).

ETYMOLOGY. From Hopevale near the sample location.

FIG. 13. *Longidigitis auripontiformis* sp. nov.; composite drawing whole worm ventral. Scalebar 50μm.

DESCRIPTION. Eyes two pairs, rarely one. Dorsal anchors slightly smaller than ventral, with well-developed elongated points, inner roots, reduced outer roots with conspicuous bump on inner curve of shaft. Ventral anchor well-developed inner roots, reduced outer roots. Ventral bar arcuate, not tapering laterally, ends square with protuberance directed anteriorly.

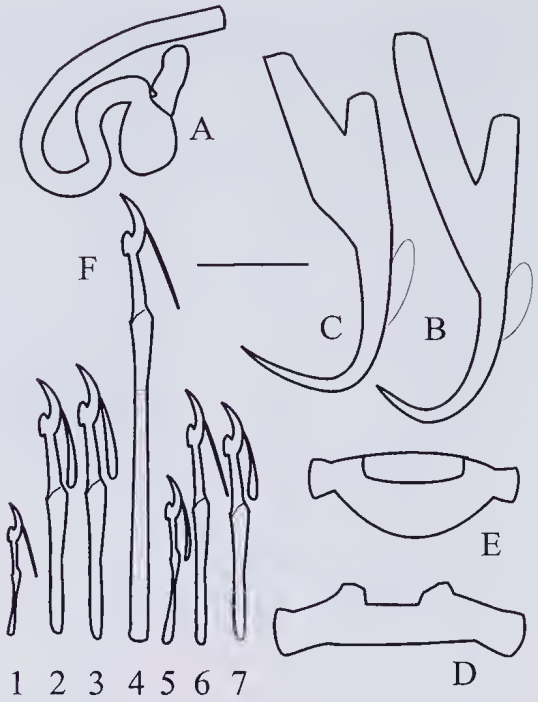

FIG. 14. *Longidigitis auripontiformis* sp. nov; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

Dorsal bar, semi-circular, with lateral extensions, posteromedial notch present, thick infill present on anterior edge. Hooks H7 smaller than H2, H6 smaller than H3, H1 and H5 much smaller than H6. Copulum shaft thin; accessory piece well-developed. Vas deferens with partially sclerotised seminal vesicle, extending from copulum to intestinal crus loop. Vagina tubular, usually inconspicuous.

REMARKS. See *L. auripontiformis* sp. nov.

Longidigitis robustus sp. nov.
(Fig. 16, Table 4)

MATERIAL HOLOTYPE QM G218882 and PARATYPES QM G219195. All from *Melanotaenia splendida splendida*, Bluewater Creek, Qld, (19°18'S, 146°45'E).

ETYMOLOGY. Named after the robust anchors.

DESCRIPTION. Eyes one pair, rarely two. Dorsal anchors slightly smaller than ventral, with well-developed elongated points, well-developed thickened inner, outer roots, outer roots slightly reduced in length. Ventral bar arcuate, ends

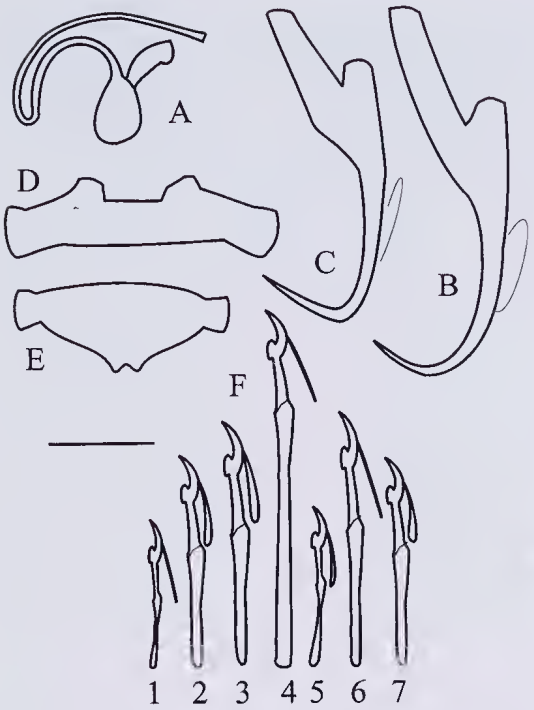

FIG. 15. *Longidigitis hopevalensis* sp. nov; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

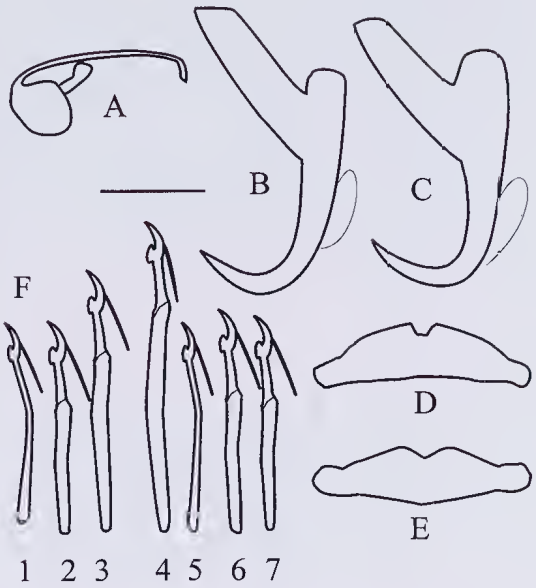

FIG. 16. *Longidigitis robustus* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

square with protuberance directed anteriorly. Dorsal bar expanded medially, tapering laterally, posteromedial notch present, thick membranous infill present on anterior edge. Hooks H7 and H2 of equal length, H6 smaller than H3, H2 slightly smaller than H6. Copulum shaft thin, with highly reduced loop; accessory piece well-developed. Vas deferens inconspicuous. Vagina inconspicuous.

REMARKS. This species is distinguished within the genus by robust anchors and shape of the bars.

Longidigitis maccullochii sp. nov.
(Fig. 17, Table 4)

MATERIAL. HOLOTYPE QM G218828 and PARATYPES QM218829-218833. All from *Melanotaenia maccullochi*, McIvor River, Qld, (15°03'S 145°26'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes two pairs. Dorsal anchors slightly smaller than ventral, both with well-developed recurved points, inner, outer roots. Ventral bar triangular, with lateral extremities tapered. Dorsal bar of similar size to ventral, consisting of an inverted arch, transversely elongate with lateral extensions; thin membranous infill absent on anterior edge; posteromedial notch absent. Hooks H2 slightly smaller than H7, H6 smaller than H3, H1 and H5 much smaller than H6. Copulum shaft thin; accessory piece lightly sclerotised, anterior end directed away from inner edge of copulum shaft. Vas deferens not sclerotised; seminal vesicle partially sclerotised, formed by bulbate dilation of vas deferens just posterior to copulum base. Vagina elongate tube.

REMARKS. This species is most similar to *L. utcheei* sp. nov. It differs in the size of the copulum shaft and shape of the bar structure.

Longidigitis utcheei sp. nov.
(Fig. 18, Table 4)

MATERIAL. HOLOTYPE QM G219473 and PARATYPES QM G219474-219477. All from *Cairnsichthys rhombosomoides*, Utchee Creek, Qld, (17°37 S 145°56 E).

ETYMOLOGY. Named after the type-host collection site.

DESCRIPTION. Eyes two pairs, anterior or dorsal to pharynx. Anchors with well-developed

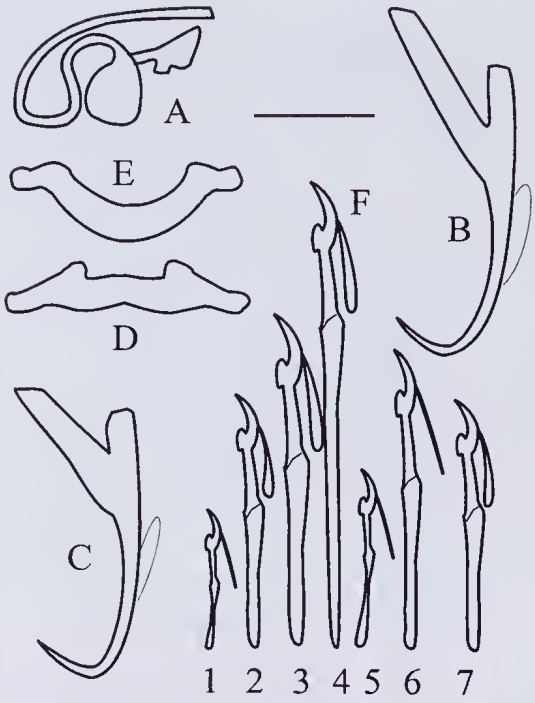

FIG. 17. *Longidigitis maccullochii* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

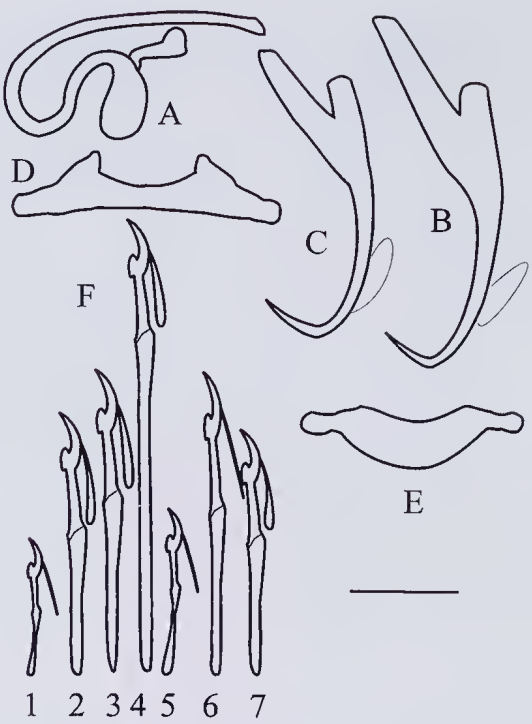

FIG. 18. *Longidigitis utcheei* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

recurved points and inner and outer roots; dorsal anchors much smaller than ventral. Ventral bar inverted V, tapering laterally. Dorsal bar slightly smaller than ventral; consisting of a shallow inverted arch, with lateral extensions, thin membranous infill reduced on anterior edge, posteromedial notch absent. Hooks H2 slightly longer than H7, H3 and H6 of similar length, H1 and H5 much smaller than H6. Copulum shaft thick; accessory piece slightly sclerotised. Seminal vesicle non-sclerotised. Vagina inconspicuous.

REMARKS. See remarks for *L. maccullochii* sp. nov.

Longidigitis gracilis sp. nov.
(Fig. 19, Table 4)

MATERIAL. HOLOTYPE QM 218845 and PARATYPES QM G218846-218849. All from *Melanotaenia utcheensis*, Utchee Creek, Qld, (17°37 S 145°56 E).

ETYMOLOGY. Named after the thin copulum shaft.

DESCRIPTION. Eyes two pairs. Dorsal and ventral anchors with well-developed recurved points, inner, outer roots. Dorsal anchors slightly smaller than ventral. Dorsal bar slightly smaller than ventral, consisting of a shallow inverted arch with lateral extensions, thin membranous infill absent on anterior edge, posteromedial notch present. Ventral bar straight, tapering laterally. Hooks H2 and H7 of similar length, H3 and H6 of similar length, H1 and H5 much smaller than H6. Copulum shaft thin; accessory piece thin partially sclerotised. Seminal vesicle non-sclerotised. Vagina tubular, usually inconspicuous.

REMARKS. This species is similar to *L. maccullochii* sp. nov. and *L. utcheei* sp. nov. It differs by having a posteromedial notch on the dorsal bar and the size of the copulum shaft.

Iliocirrus gen. nov.

TYPE SPECIES AND HOST. *I. iliocirrus* sp. nov. from *M. s. splendida*, Bluewater Creek, Qld, (19°18'S 146°45'E).

ETYMOLOGY. Latin *ilios*, twisted and *cirrus*, hair; referring to the form of the copulum shaft.

DIAGNOSIS. Body minute (rarely >150μm), divisible into cephalic, trunk, peduncle, haptoral

TABLE 4. Morphometric measurements (μm) of *Longidigitis* species. Means and standard error. ME, number of parasites measured; BL, body length; BW, body width; HW, haptor width; HL, haptor length; PD, pharynx diameter; DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. ( ) range.

	L. auripontiformis	*L. hopevalensis*	*L. robustus*	*L. maccullochii*	*L. utcheei*	*L. gracilis*
ME	35	16	20	47	27	31
BL	(120-160)	(110-140)	(130-220)	(90-160)	(120-190)	(110-140)
BW	(35-60)	(40-70)	(50-90)	(40-70)	(50-80)	(50-70)
HL	(25-50)	(20-40)	(30-50)	(25-60)	(30-50)	(25-40)
HW	(60-95)	(50-70)	(50-80)	(50-80)	(55-80)	(50-80)
PD	(9-12)	(9-12)	(13-17)	(9-13)	(11-15)	(9-11)
DA1	9.4 ± 0.14	7.9 ± 0.18	6.4 ± 0.26	5.52 ± 0.09	6.2 ± 0.21	5.0 ± 0.14
DA2	30.7 ± 0.31	29.4 ± 0.26	26.2 ± 0.26	23.00 ± 0.18	27.0 ± 0.49	20.6 ± 0.24
DA3	23.8 ± 0.21	22.0 ± 0.26	19.2 ± 0.28	17.81 ± 0.17	20.8 ± 0.20	15.8 ± 0.20
DA4	27.2 ± 0.23	24.5 ± 0.26	22.4 ± 0.27	20.27 ± 0.19	23.9 ± 0.28	19.0 ± 0.23
DA5	9.7 ± 0.19	10.8 ± 0.40	10.8 ± 0.31	6.96 ± 0.13	7.4 ± 0.28	6.0 ± 0.20
DA6	13.0 ± 0.25	11.9 ± 0.41	12.4 ± 0.48	8.27 ± 0.14	9.9 ± 0.14	8.8 ± 0.24
VA1	5.4 ± 0.13	6.1 ± 0.17	6.3 ± 0.22	4.62 ± 0.08	5.4 ± 0.13	5.1 ± 0.17
VA2	34.7 ± 0.39	34.2 ± 0.26	27.2 ± 0.31	27.65 ± 0.24	31.7 ± 0.36	23.4 ± 0.26
VA3	22.8 ± 0.24	24.1 ± 0.27	18.7 ± 0.35	18.87 ± 0.19	22.1 ± 0.19	16.6 ± 0.18
VA4	28.5 ± 0.20	27.1 ± 0.34	21.9 ± 0.26	22.85 ± 0.22	26.3 ± 0.28	20.4 ± 0.22
VA5	13.5 ± 0.27	12.7 ± 0.21	11.8 ± 0.36	11.13 ± 0.18	11.4 ± 0.33	8.8 ± 0.23
VA6	12.6 ± 0.24	13.1 ± 0.30	13.1 ± 0.30	9.94 ± 0.24	10.9 ± 0.18	10.0 ± 0.23
DB1	19.2 ± 0.27	19.4 ± 0.27	20.7 ± 0.36	17.79 ± 0.15	20.7 ± 0.29	19.3 ± 0.32
DB2	0.00	0.0	0.00	,00	0.00	4.4 ± 0.16
DB3	7.8 ± 0.18	8.6 ± 0.15	5.9 ± 0.19	5.33 ± 0.10	5.4 ± 0.14	5.6 ± 0.20
VB1	22.7 ± 0.25	25.7 ± 0.34	20.4 ± 0.20	19.54 ±0.16	25.0 ± 0.29	23.1 ± 0.31
VB2	8.6 ± 0.15	9.6 ± 0.12	5.2 ± 0.66	8.02 ± 0.13	9.4 ± 0.18	11.2 ± 0.24
H1	13.2 ± 0.17	14.1 ± 0.26	12.4 ± 0.44	11.96 ± 0.13	12.4 ± 0.26	11.0 ± 0.21
H2	22.9 ± 0.27	21.0 ± 0.20	19.2 ± 0.35	20.83 ± 0.20	24.0 ± 0.41	18.8 ± 0.25
H3	24.4 ± 0.24	22.8 ± 0.28	24.0 ± 0.37	26.65 ± 0.27	27.5 ± 0.46	22.7 ± 0.31
H4	41.0 ± 0.32	33.3 ± 0.33	28.8 ± 0.42	36.94 ± 0.27	40.7 ± 0.64	36.7 ± 0.31
H5	16.4 ± 0.21	16.1 ± 0.20	15.9 ± 0.36	14.08 ± 0.12	15.2 ± 0.16	14.3 ± 0.35
H6	23.6 ± 0.24	24.2 ± 0.28	23.6 ± 0.49	24.10 ± 0.20	28.8 ± 0.46	21.6 ± 0.24
H7	22.1 ± 0.26	20.2 ± 0.28	19.6 ± 0.38	21.58 ± 0.22	23.1 ± 0.41	18.4 ± 0.16

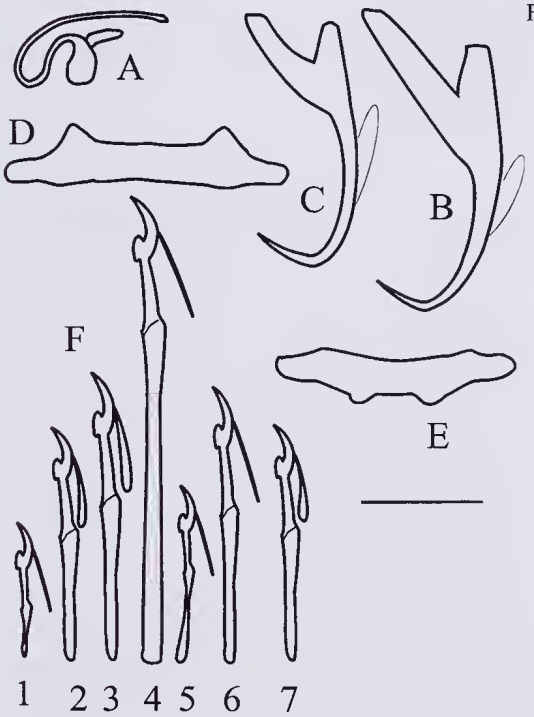

FIG. 19. *Longidigitis gracilis* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

regions. Tegument thin, smooth. Head organs three pairs; cephalic lobes and glands present. Mouth subterminal, midventral; pharynx muscular; intestine bifurcate, united posterior to gonads. Eyes rarely two pairs, commonly one, anterior or dorsal to pharynx, anterior eyes, when present, consisting of scattered granules. Gonads intercaecal; ovary trianguloid, in middle part of body; testis single, oval to elliptical, smaller than ovary, overlapping ovary dorsally. Vas deferens originating from anterior end of testis, looping intestinal crus sinistrally, joining copulum base posterodextrally; seminal vesicle non-sclerotised, formed by dilation of vas deferens; prostatic reservoir, single terminating dextral to copulum base. Copulum sclerotised, shaft originating from anterior end of copulum base, consisting of a double sinistral recurved loop (Type IV copulatory apparatus, Fig. 26D), distal end arches anterior to copulum base, directed to dextral side of body, terminating

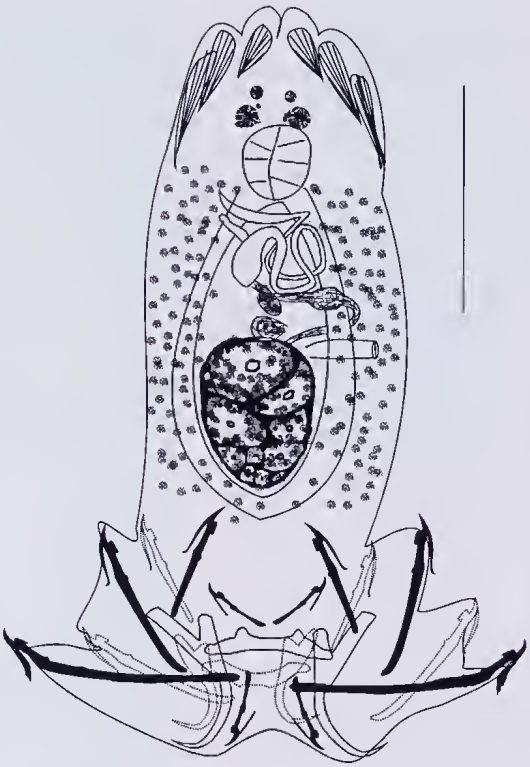

FIG. 20. *Iliocirrus iliocirrus* sp. nov.; composite drawing whole worm, ventral. Scalebar 50μm.

dextral to copulum base; base bulbate; accessory piece thumb shaped, directed anteriorly; spiral filament absent. Vagina, non-sclerotised, opening dextromarginal; seminal receptacle formed by dilation of vagina, at distal end, anterior to ovary. Vitellaria coextensive with intestine, lateral and posterior to crura. Haptor well set off from body, wider than body, sub-hexagonal. Anchors two pairs, well-developed, opposed dorso-ventrally (Fig. 2A); dorsal anchors much smaller than ventral. Transverse bars two, not articulated; ventral bar laterally elongate, two knobs directed anteriorly third of length from end, usually tapering laterally, rarely with expansions at ends; dorsal bar arcuate, with lateral extensions, medial notch present on posterior surface, smaller than ventral. Hooks 14, six pairs (H2-H7) marginal, pair one more central, five pairs ventral, two pairs dorsal (H6-7), H7 anterior to ventral anchors; handle length increases from H1 to H4, H4 always longer than the anchors; hook shaft and handle equally prominent, handle with expanded demarcation; wing process present. Parasites of freshwater atherinform fishes.

OTHER SPECIES: *Iliocirrus trifasciatae* sp. nov. from *M. trifasciata*, *I. mazlini* sp. nov. from *M. eachamensis* and *Melanotaenia utcheensis*, *I. ornatusi* sp. nov. from *Rhadinocentrus ornatus* Regan, 1914, *I. rossi* sp. nov. from *C. s. stercusmuscarum*.

Iliocirrus iliocirrus sp. nov.
(Fig. 20-21, Table 5)

MATERIAL. HOLOTYPE QM G219468 and PARATYPES QM G219469-72. All from *Melanotaenia splendida splendida*, Bluewater Creek, Qld, (19°18'S 146°45'E).

ETYMOLOGY. As for genus.

DESCRIPTION. Eyes one pair, rarely two. Vas deferens, non-sclerotised; seminal vesicle consisting of expanded bulb at point of loop around intestine. Copulum shaft consisting of a thick well-developed double sinistral recurved loop, distal end with pronounced sickle-shape expansion; accessory piece thin lightly sclerotised. Vagina tubular. Anchors with well-developed recurved points, shaft, blade present; ventral anchor with well-developed inner, outer roots; dorsal anchors much smaller than ventral, with reduced inner, outer roots. Dorsal bar shallow inverted arch; ventral bar ends tapering laterally. Hooks H7 slightly smaller than H2, H6 slightly smaller than H3, H1 and H5 much smaller than H6.

REMARKS. This species is most similar to *I. rossi*. sp. nov. It is easily distinguished by morphometric variation and the copulum shaft thickness.

Iliocirrus rossi sp. nov.
(Fig. 22, Table 5)

MATERIAL. HOLOTYPE QM G219463 and PARATYPES QM G219464-219467. All from *Craterocephalus stercusmuscarum stercusmuscarum*, Ross River, Qld, (19°18'S 146°45'E).

ETYMOLOGY. Named after the type host locality.

DESCRIPTION. Eyes one pair, rarely two. Anchors with well-developed recurved points, shaft, blade present; ventral anchors with well developed inner, outer roots; dorsal anchors much smaller than ventral, reduced inner roots, outer roots. Ventral bar with ends tapering laterally; dorsal bar inverted bell curve, with lateral extensions at extremities, slightly smaller than ventral. Hooks H7 slightly smaller than H7, H6 much smaller than H3, H1 and H5 much smaller than H6. Copulum shaft consisting of a thin well-developed double sinistral recurved loop, distal end with sickle-shape expansion; accessory piece thin, lightly sclerotised. Vas deferens, non-sclerotised; seminal vesicle consisting of

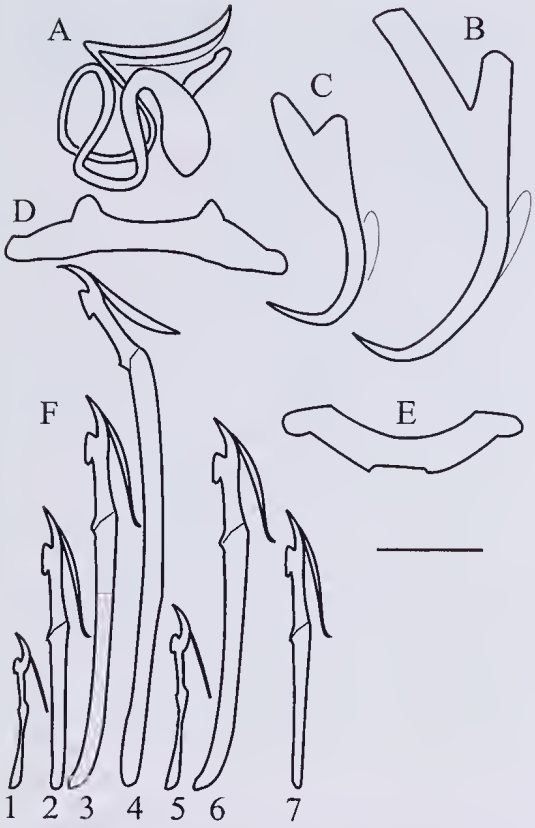

FIG. 21. *Iliocirrus iliocirrus* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

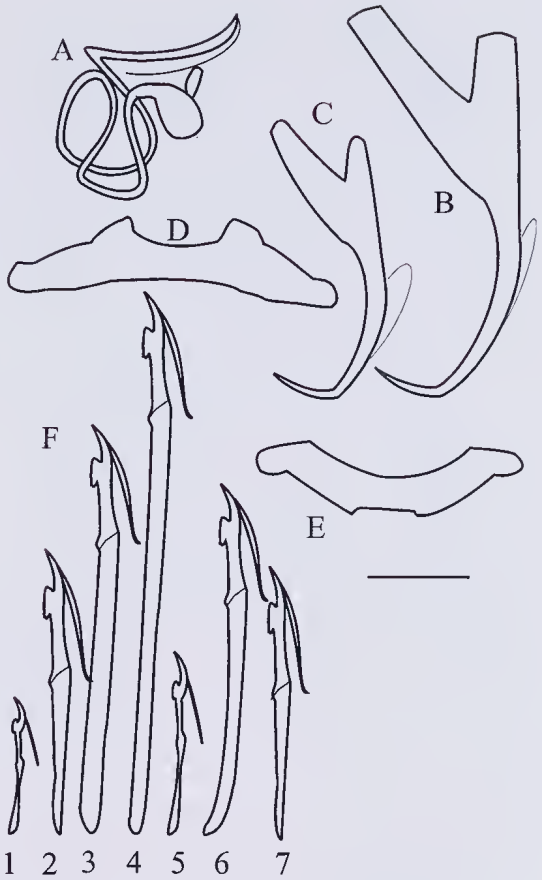

FIG. 22. *Iliocirrus rossi* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

expanded bulb at point of loop around intestine. Vagina tubular. This species is not visually discernable from *I. iliocirrus*. Morphometric variation used as criteria for species recognition.

REMARKS. See *L. iliocirrus* sp. nov. and morphometric analysis.

Iliocirrus trifasciatae sp. nov.
(Fig. 23, Table 5)

MATERIAL. HOLOTYPE QM G218872 and PARATYPES QM G218873-218876. All from *Melanotaenia trifasciata*, McIvor River, Qld, (15°09'S 145°26'E).

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes two pairs, anterior eyes usually a few dispersed granules. Anchors shaft, blade present; point well-developed; dorsal anchors much smaller than ventral; with reduced inner, outer roots. Ventral bar with ends tapering laterally; dorsal bar slightly smaller than ventral, consisting of a deep inverted arch with lateral extensions. Hooks H2 slightly longer than H7, H3 and H6 of similar length, H1 and H5 much smaller than H6. Copulum shaft thin, with loop reduced; accessory piece reduced, lightly sclerotised. Seminal vesicle non-sclerotised. Vagina tubular, usually inconspicuous.

REMARKS. This species is most similar to *I. iliocirrus* sp. nov. and *I. rossi* sp. nov. in the size and shape of the haptoral sclerites. It differs from these species by the shape of the copulum shaft.

Iliocirrus ornatusi sp. nov.
(Fig. 24, Table 5)

MATERIAL. HOLOTYPE QMG218867 and PARATYPES QMG218868-218871. All from *Rhadinocentrus ornatus*, Brunswick River, New South Wales, (28°70'S, 151°50'E).

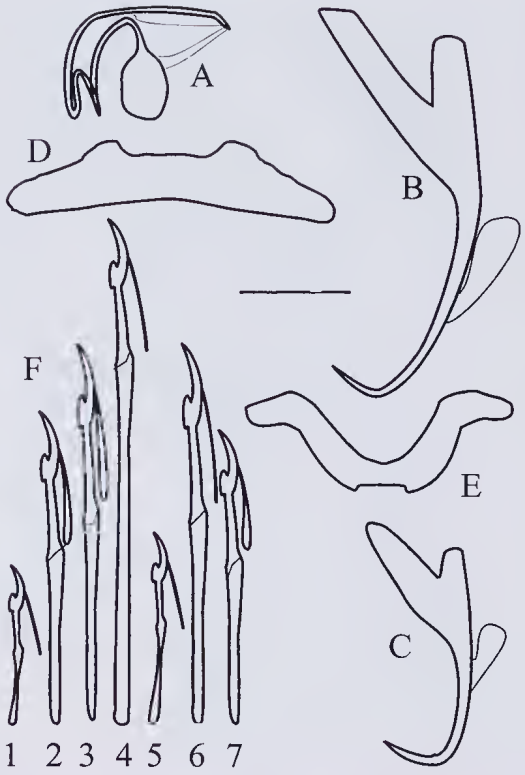

FIG. 23. *Iliocirrus trifasciatae* sp. nov.; A, ♂ copulatory apparatus(dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

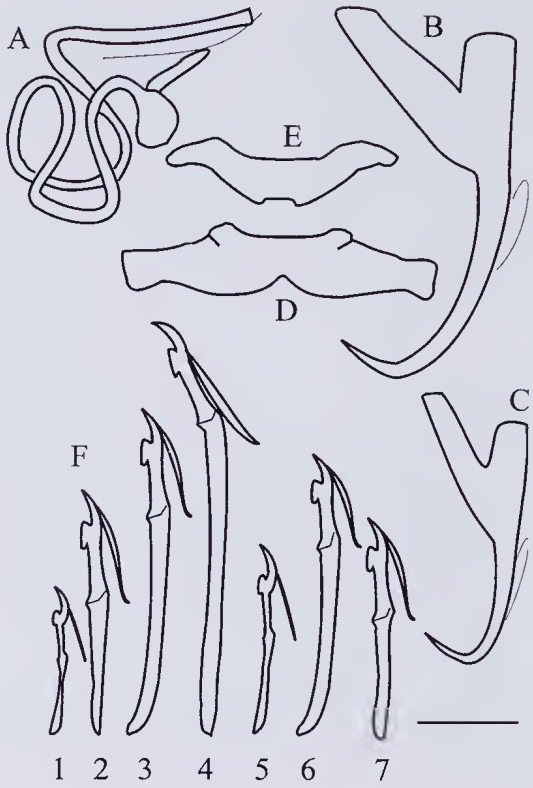

FIG. 24. *Iliocirrus ornatusi* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

ETYMOLOGY. Named after the type host.

DESCRIPTION. Eyes 2 pairs, anterior or dorsal to pharynx. Anchors shaft, blade present; point well-developed; ventral anchors with well-developed inner, outer roots; dorsal anchors much smaller than ventral, highly reduced inner, outer roots. Ventral bar with ends expanded and square, V-shaped notch present on posteromedial edge; dorsal bar slightly smaller than ventral, deep inverted arch. Hooks H7 smaller than H2, H6 smaller than H3, H1 and H5 much smaller than H6. Copulum shaft thin, distal end straight tube; accessory piece reduced, lightly sclerotised. Seminal vesicle inconspicuous. Vagina tubular, usually inconspicuous.

REMARKS. This species is most similar to *I. mazlini* having similar hook length ratios. It differs in the shape of the ventral bar and ventral anchor.

Iliocirrus mazlini sp. nov.
(Fig. 25, Table 5)

MATERIAL. HOLOTYPE QMG218839 and PARATYPES QMG218840-218844. All from *Melanotaenia eachamensis*, Dirran Creek, Qld, (17°27'S, 145°06'E).

ETYMOLOGY. For Rob Mazlin who helped me with collections and kept me inspired.

DESCRIPTION. Eyes 2 pairs. Anchors shaft, blade present; point well-developed; ventral anchors with well-developed inner, outer roots, distinct bump present on outer curve of blade; dorsal anchors much smaller than ventral, highly reduced inner, outer roots. Ventral bar inverted V, tapering laterally; dorsal bar slightly smaller than ventral, deep inverted arch. Hooks H7 much smaller than H2, H6 smaller than H3, H1 and H5 much smaller than H6. Copulum shaft thin; base elongate; accessory piece elongate, thin, partially

sclerotised. Seminal vesicle inconspicuous. Vagina tubular.

REMARKS. See *I. ornatusi* sp. nov.

REMARKS ON MORPHOLOGICAL CHARACTERISTICS

Copulatory Apparatus Structure. Four types are identified (Fig. 26A-D).

Type I. A type I copulatory apparatus identifies species of *Recurvatus* and consists of a ball-shaped base with the shaft emanating from the right-anterior side. The shaft consists of a thin tube forming a counter-clockwise curving single loop (ventral view), which encircles the base. The distal end of the shaft terminates anterior to and to the right of the base. The accessory piece is attached to the anteromedial end of the base, dextral to the copulum shaft.

Type II. A type II copulatory apparatus identifies *Helicirrus* and consists of a single teardrop-shaped base with the shaft emanating from the anteromedial end. The shaft projects anteriorly initially then sharply reverses direction to continue left and posteriorly to the base, ending in a helix anteriorly to gonads. A thin spike-shaped accessory piece projects anteriorly from the right anterior end of the copulum base and to the right of the shaft. A long thin filament arises from near the anterior end of the shaft. This filament was not observed in live specimens or most permanent mounts but was easily discernable when the internal fluids of the parasite were extruded in preserved material using Malmberg's glycerol-ammonium-picrate. This was also the case for the vas deferens.

Type III. A type III copulatory apparatus identifies species of *Longidigitis* and consists of a bulbate base with the shaft emanating from the anterior end. The shaft consists of a tube with a single sinistral loop with distal end anterodextral to the base. The accessory piece is sclerotised; thumb shaped and arises from the anterosinistral side of the shaft.

Type IV. A type IV copulatory apparatus identifies species of *Iliocirrus* and consists of a bulbate base with the shaft arising from the anterior end. The shaft consists of a tube with two sinistral loops. The first loop is posterosinistral and the second loop anterosinistral to base. The copulum shaft distal end is anterior and to the right of the base. The accessory piece is sclerotised; thumb shaped and emanates from the right-anterior side of the copulum.

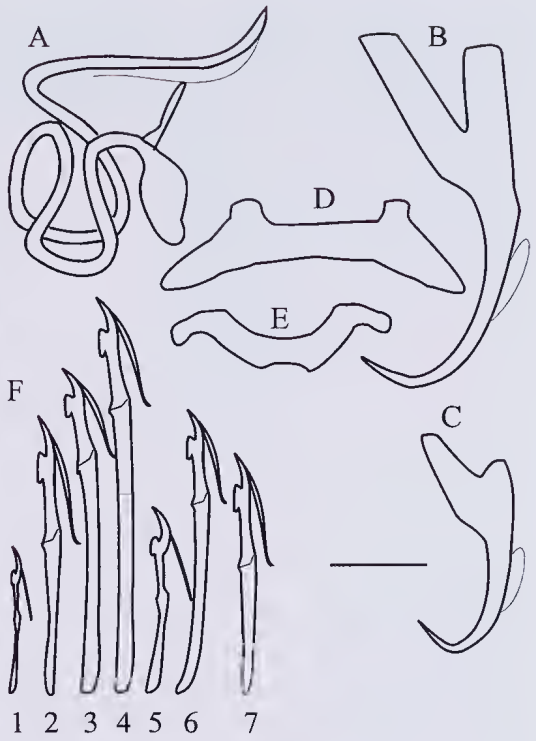

FIG. 25. *Iliocirrus mazlini* sp. nov.; A, ♂ copulatory apparatus (dorsal); B, ventral anchor; C, dorsal anchor; D, ventral bar; E, dorsal bar; F, hooks 1-7. Scalebar 10μm.

Haptoral Structure. The haptoral sclerite morphology can be discussed in three parts, anchors, bars and hooks. In the new genera proposed here, variations of these characters do not clearly reflect generic groupings.

Anchors have a large variation in size and shape although two patterns are recognised. Pattern one has dorsal anchors slightly smaller than ventral, while pattern two has dorsal anchors much smaller than ventral. Pattern one is seen in all species of *Recurvatus* and *Longidigitis*, but also occurs in several species of *Helicirrus*. For *Helicirrus*, pattern one occurs in *H. mcivori*, *H. gertrudaea* and *H. marjoriaea*. Pattern 2 occurs in all species of *Iliocirrus* and three species of *Helicirrus*, *H. splendidae*, *H. megaloanchor* and *H. maccullochii* and is associated with the reduced hook pattern (see below).

The dorsal bar has 3 morphological variants. The simple arch with the anteromedial membrane occurred in *L. auripontiformis*, *L. hopevalensis* and *L. robustus*. The second variant of the dorsal bar possesses a posteromedial notch as in *L.*

gracilis and all species of *Iliocirrus*. The third variant is the highly reduced dorsal bar which is observed as a thin filament and occurs in *H. splendidae*, *H. megaloanchor* and *H. maccullochii*. All species of *Recurvatus* and *L. maccullochii*, *L. utcheei*, *H. mcivori*, *H. marjoriaea* and *H. gertrudaea* have a well-developed arched dorsal bar and lacking both the medial notch and the anteromedial membrane.

Hook lengths show two character patterns that are spread across members of more than one genus. In the first pattern, hooks are of reduced form; all smaller than ventral anchors with the dorsal hooks H6 always longest. This pattern is found *in H. splendidae*, *H. megaloanchor* and *H. maccullochii* and is also associated with highly reduced dorsal anchors and bar. The second pattern, occurring in members of all four genera, consists of elongated hooks and widely differing lengths though generally increasing from H1 to H4. Ventral hook H4 is always the longest and always longer than the ventral anchors.

TABLE 5. Morphometric measurements (μm) of *Iliocirrus* species. Means and standard error. ME, number of parasites measured; BL, body length; BW, body width; HW, haptor width; HL, haptor length; PD, pharynx diameter; DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. ( ) range.

	I. iliocirrus	*I. trifasciatae*	*I. rossi*	*I. ornatusi*	*I. mazlini*
ME	49	31	33	51	32
BL	(100-160)	(100-170)	(100-160)	(120-180)	(130-220)
BW	(40-90)	(35-80)	(35-60)	(40-90)	(50-140)
HL	(25-50)	(20-40)	(30-60)	(25-60)	(25-50)
HW	(70-110)	(65-120)	(70-110)	(60-100)	(70-110)
PD	(7-13)	(9-13)	(9-13)	(12-18)	(12-21)
DA1	5.7 ± 0.11	5.3 ± 0.16	6.0 ± 0.15	5.5 ± 0.10	5.7 ± 0.13
DA2	22.2 ± 0.22	22.8 ± 0.15	27.4 ± 0.30	24.7 ± 0.21	22.5 ± 0.22
DA3	17.0 ± 0.18	17.1 ± 0.15	20.7 ± 0.21	18.1 ± 0.18	17.8 ± 0.28
DA4	19.8 ± 0.21	19.7 ± 0.25	24.9 ± 0.20	21.9 ± 0.20	20.5 ± 0.19
DA5	7.2 ± 0.16	7.6 ± 0.18	9.1 ± 0.28	8.6 ± 0.16	6.8 ± 0.17
DA6	9.7 ± 0.17	8.8 ± 0.24	10.8 ± 0.17	9.9 ± 0.16	9.5 ± 0.23
VA1	4.9 ± 0.11	4.5 ± 0.13	5.0 ± 0.16	5.2 ± 0.10	5.3 ± 0.13
VA2	32.4 ± 0.25	34.4 ± 0.21	38.1 ± 0.46	34.0 ± 0.25	36.0 ± 0.26
VA3	25.1 ± 0.20	25.3 ± 0.18	28.4 ± 0.27	24.2 ± 0.19	27.0 ± 0.24
VA4	31.0 ± 0.26	32.5 ± 0.24	35.5 ± 0.41	30.4 ± 0.25	34.9 ± 0.34
VA5	12.3 ± 0.21	13.5 ± 0.21	14.2 ± 0.33	12.5 ± 0.20	13.7 ± 0.23
VA6	14.3 ± 0.19	14.7 ± 0.16	15.9 ± 0.22	13.9 ± 0.19	15.6 ± 0.19
DB1	22.4 ± 0.24	24.1 ± 0.38	24.4 ± 0.34	23.6 ± 0.23	23.3 ± 0.34
DB2	3.9 ± 0.07	4.7 ± 0.17	5.9 ± 0.19	3.7 ± 0.07	4.8 ± 0.14
DB3	7.2 ± 0.12	9.1 ± 0.22	7.2 ± 0.18	7.1 ± 0.11	7.4 ± 0.16
VB1	26.5 ± 0.24	29.8 ± 0.27	30.8 ± 0.28	30.7 ± 0.24	30.9 ± 0.49
VB2	11.8 ± 0.16	10.5 ± 0.16	10.8 ± 0.20	12.2 ± 0.15	14.5 ± 0.22
H1	14.1 ± 0.15	14.2 ± 0.15	14.2 ± 0.18	13.4 ± 0.15	14.1 ± 0.13
H2	25.7 ± 0.23	27.6 ± 0.29	27.4 ± 0.29	24.2 ± 0.23	27.7 ± 0.36
H3	36.2 ± 0.30	33.0 ± 0.34	37.8 ± 0.30	30.6 ± 0.30	33.0 ± 0.47
H4	48.5 ± 0.31	44.6 ± 0.57	49.9 ± 0.34	37.9 ± 0.31	39.1 ± 0.39
H5	17.4 ± 0.16	17.4 ± 0.17	17.5 ± 0.20	17.6 ± 0.16	19.4 ± 0.22
H6	33.9 ± 0.27	33.5 ± 0.22	33.0 ± 0.38	27.1 ± 0.26	27.8 ± 0.33
H7	25.4 ± 0.24	25.9 ± 0.25	25.6 ± 0.47	21.5 ± 0.24	21.8 ± 0.24

Several patterns of associated hook lengths are identified in the elongated form. Size differences between H2 and H7 have three patterns: H2 is longer than H7 in *I. ornatusi*, *I. mazlini*, *I. trifasciatae*, *L. auripontiformis*, *L. utcheei*, and *H. marjoriaea*; H2 equals H7 in *R. chelatus*, *R. signiferi*, *I. rossi*, *I. iliocirrus*, *L. gracilis*, *L. maccullochii*, *L. robustus* and *H. mcivori*; and *Helicirrus gertrudaea* has H2 shorter than H7. Generally H3 is noticeably longer than H6; however in *I. trifasciatae* and *L. utcheei*, H3 and H6 are of similar size. Most species have hooks H3 longer than H2, but this is reversed for *R. signiferi*.

Morphometrics. Means and ranges of measured soft body characters, and means and standard error of haptoral sclerite measurements are shown in Tables 2-5. Soft body measurements show large variation and are influenced by preparation method. Slide preparations that used formalin-preserved parasites (technique two) had much smaller soft body dimensions than those prepared by technique one (unpubl. data). This is an important point when considering comparing species from other studies. However, several species show visual size differences in body width. *Helicirrus splendidae*, *H. maccullochii*, *I. mazlini* and *I. ornatusi* have greater body widths than other species examined. *Iliocirrus mazlini* and *I. ornatusi* are easily distinguished from other species of the genus based on this observation.

MULTIVARIATE ANALYSIS. Using Scheffé test between-subjects MANOVA, a significant difference between means was observed among species of *Longidigitis* using Wilks' λ ($F_{(92, 513)}$ =43.2, $p<0.01$), among *Iliocirrus* species using Wilks' λ ($F_{(96, 596)}$=30.5, $p<0.01$), among *Helicirrus* species using Wilks' λ ($F_{(115, 618)}$ =31.0, $p<0.01$) and among *Recurvatus* species using Wilks' λ ($F_{(23, 57)}$=145.7, $p<0.01$). Thus, some species are significantly different within each genus. A between-subjects effect

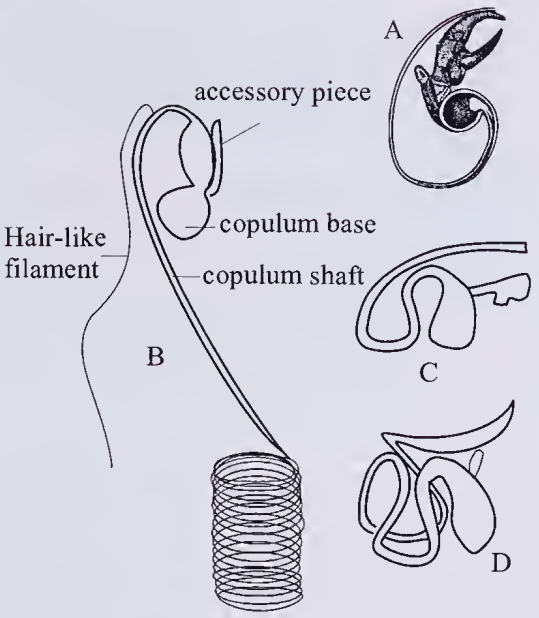

FIG. 26. Copulum types; A, '*Recurvatus*' type I; B, '*Helicirrus*' type II; C, '*Auripontiformis*' type III; D, '*Iliocirrus*' type IV.

MANOVA showed a significant difference between character means for species of *Longidigitis* ($p<0.01$). A significant difference ($p<0.01$) between means for species of *Recurvatus* was observed for all variables except DA5 and DA2, ($p<0.01$) and DA1, VA6 and VA2 ($p>0.05$). For *Helicirrus* species a significant difference ($p<0.01$) between means was observed for all variables. For *Iliocirrus* species a significant difference ($p<0.01$) between means was observed for all variables except DA1 ($p<0.05$) and VA6 ($p>0.05$).

A MANOVA using Scheffé test for pair-wise comparisons of species within each genus ($P<0.01$) showed the maximum number of significantly different variable means between any two species was 21 of the possible 24 variables measured, while the minimum was seven. The maximum difference of 21 occurred between *L. gracilis* and *L. hopevalensis* (Table 7) and *H. splendidae* and *H. gertrudaea* (Table 7). A minimum of seven significant differences ($p<0.01$) occurred between *H. gertrudaea* and *H. marjoriaea* (Table 6) and between *L. hopevalensis* and *L. auripontifomis* (Table 7). For *Iliocirrus* species, the maximum was 17 between *I. iliocirrus* and *I. mazlini* (Table 8) and between *I. rossi* and *I. ornatusi* (Table 8). The minimum for *Iliocirrus*

TABLE 6. Species of *Helicirrus* and statistically significant ($\propto = 0.01$) morphometric character differences using Scheffé pairwise comparisons. ( ) indicates number of significant character differences. *Characters identified as significantly different using Tukey's HSD test.

SPECIES	MINIMUM DIFFERENCE	MAXIMUM DIFFERENCE
H. splendidae	*H. maccullochii* (10) (15)* *H. megaloanchor* (13) (14)* *H. mcivori* (13) (18)*	*H. marjoriaea* (20) (22)* *H. gertrudaea* (17) (20)*
H. maccullochii	*H. splendidae* (10) (15)* *H. megaloanchor* (15) (16)*	*H. marjoriaea* (18) (20)* *H. gertrudaea* (16) (20)* *H. mcivori* (20) ((22)*
H. megaloanchor	*H. gertrudaea* (18) (22)*	*H. marjoriaea* (18) ((20)* *H. mcivori* (19) (21)*
H. mcivori	*H. gertrudaea* (7) (13)* *H. marjoriaea* (13) (21)*	*H. megaloanchor* (19) (21)*
H. gertrudaea	*H. marjoriaea* (11) (17)*	*H. megaloanchor* (18) (22)*
H. marjoriaea	*H. gertrudaea* (11) (17)*	*H. splendidae* (21) (22)*

species was eight between *I. trifasciatae* and *I. rossi* (Table 8). For the *Recurvatus* species, the difference was 18. A MANOVA using Tukey's HSD test for pairwise comparisons ($P<0.01$) of species within each genus identified more significant differences. The minimum number of significantly different variable means between any two species was 13; between *H. mcivori* and *H. gertrudaea* (Table 6). A maximum of 22 occurred between species as follows: *H. maccullochii* and *H. marjoriaea*; *H. megaloanchor* and *H. gertrudaea*; *H. gertrudaea* and *H. splendidae*; *H. marjoriaea* and *H. splendidae*; *H. maccullochii* and *H. mcivori*; *L. gracilis* and *L. hopevalensis* and *L. utcheei*; *L. auripontiformis* and *L. gracilis* and *L. maccullochi*; *I. rossi* and *I. ornatusi*.

PRINCIPAL COMPONENT ANALYSIS. Initially all analyses were run to examine communalities between variables and functions. All variables with communalities <0.7 were removed and a final analysis was done. For all species analysed together, PCA extracted four components after the removal of characters DB2, VA1, H1, and H5. The four components accounted for 84.4 % of the explained variance. PC1 accounted for 48.3%, PC2 accounted for 22.3% and PC3 accounted for 7.9% while PC4 accounted for 5.9%. Examination of the scatter plots showed that specimens clearly clustered into their respective genera (Fig. 27). This indicates that haptoral sclerite variation has a close correlation to copulum morphology although two clusters of *Helicirrus* species also separated from the third. These separated clusters represent *H. splendidae*, *H. maccullochii* and *H. megaloanchor* and identify the reduced hook

TABLE 7. Species of *Longidigitis* and statistically significant ($\alpha = 0.01$) morphometric character differences using Scheffé pairwise comparisons. ( ) indicates number of significant character differences. *Characters identified as significantly different using Tukey's HSD test.

SPECIES	MINIMUM DIFFERENCE	MAXIMUM DIFFERENCE
L. auripontiformis	*L. hopevalensis* (7) (18)* *L. robustus* (13) (19)* *L. utcheei* (14) (19)*	*L. gracilis* (19) (22)* *L. maccullochii* (20) (22)*
L. robustus	*L. maccullochii* (11) (20)* *L. hopevalensis* (14) (16)*	*L. gracilis* (17) (21)* *L. utcheei* (15) (18)*
L. maccullochii	*L. utcheei* (16) (19)* *L. gracilis* (17) (20)*	*L. hopevalensis* (20) (21)* *L. auripontiformis* (20) (22)*
L. utcheei	*L. hopevalensis* (14) (20)* *L. robustus* (14) (17)*	*L. gracilis* (19) (22)*
L. hopevalensis	*L. auripontiformis* (7) (18)*	*L. gracilis* (21) (22)*
L. gracilis	*L. maccullochii* (17) (20)*	*L. hopevalensis* (21) (22)*

TABLE 8. Species of *Iliocirrus* and statistically significant ($\alpha = 0.01$) morphometric character differences using Scheffé pairwise comparisons. ( ) indicates number of significant character differences. *Characters identified as significantly different using Tukey's HSD test.

SPECIES	MINIMUM DIFFERENCE	MAXIMUM DIFFERENCE
I. trifasciata	*I. rossi* (8) (16)* *I. mazlini* (9) (17)*	*I. iliocirrus* (14) (17)* *I. ornatusi* (12) (19)*
I. iliocirrus	*I. ornatusi* (12) (19)* *I. rossi* (14) (16)*	*I. mazlini* (17) (21)*
I. rossi	*I. mazlini* (11) (16)*	*I. ornatusi* (17) (22)*
I. ornatusi	*I. trifasciatae* (12) (19)* *I. iliocirrus* (12) (19)*	*I. mazlini* (15) (20)*
I. mazlini	*L. trifasciatae* (9) (17)*	*I. iliocirrus* (17) (21)*

haptor type. The main cluster, which includes all four genera, identifies the elongated hook haptor type. Dorsal anchor and hook characters dominated the first component, while ventral anchor and bar characters dominated PC2 (Table 9).

When *Helicirrus*, *Recurvatus*, *Longidigitis* and *Iliocirrus* were analysed separately, clusters of each species were generally well defined. Principal component analysis identified four components for *Recurvatus*, after the removal of eight characters: DA-6, VA3, VA6, DB1-3, H1 and H5. The four components accounted for 85.8% of the explained variance. PC1 accounted for 39.8%, PC2 accounted for 22.4% and PC3 accounted for 16.4% while PC4 accounted for 7.2% (Table 10). Examination of the scatter plots showed that species clearly separated on the first component (Fig. 28). Hooks H2-4 and H6-7 and dorsal anchor characters DA3-4 dominated the first component, ventral anchor characters VA2 and VA4-5 dominated PC2 and characters DA1 and VB2 dominated the third component (Table 10).

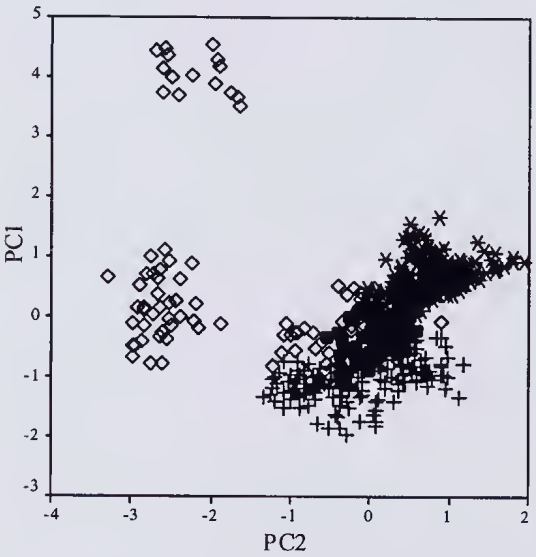

FIG. 27. Scatter plots of first two axes of principal component analysis using 20 natural log/z-score transformed metric variables for generic-level. ● *Recurvatus*; + *Longidigitis*; ✱ *Iliocirrus*; ◇ *Helicirrus*.

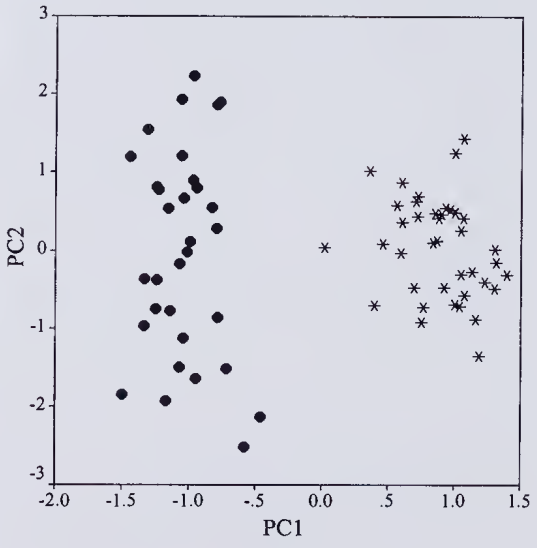

FIG. 28. Scatter plots of first two axes of principal component analysis using 16 natural log/z-score transformed metric variables for *Recurvatus* species. ✱ *R. signiferi*; ● *R. chelatus*.

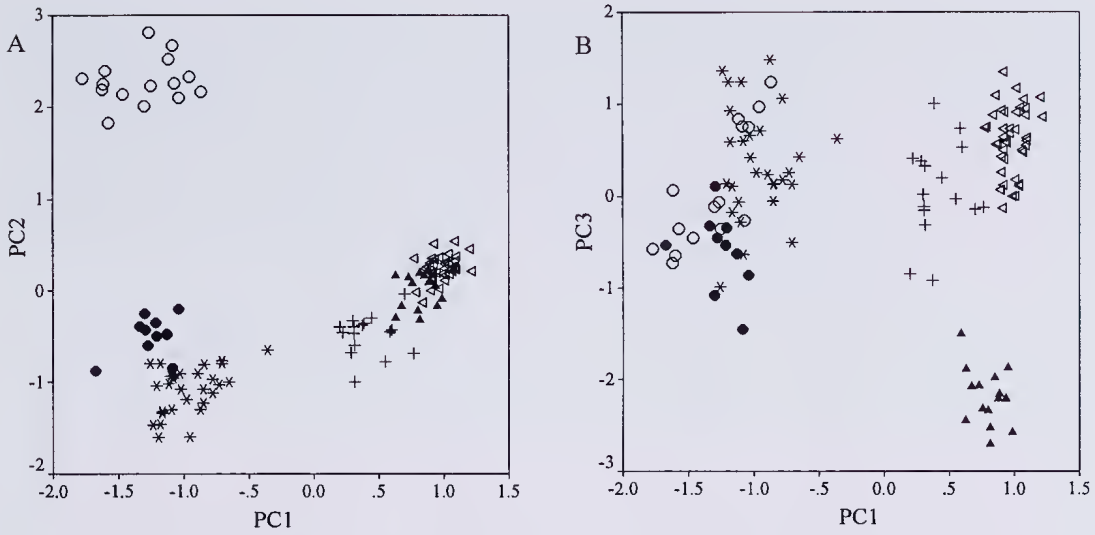

FIG. 29A-B. Scatter plots of first three axes of principal component analysis using 21 natural log/z-score transformed metric variables for *Helicirrus* species. ✶ *H. splendidae*; ○ *H. megaloanchor*; + *H. mcivori*; ◁ *H. marjoriaea*; ● *H. maccullochii*; ▲ *H. gertrudaea*.

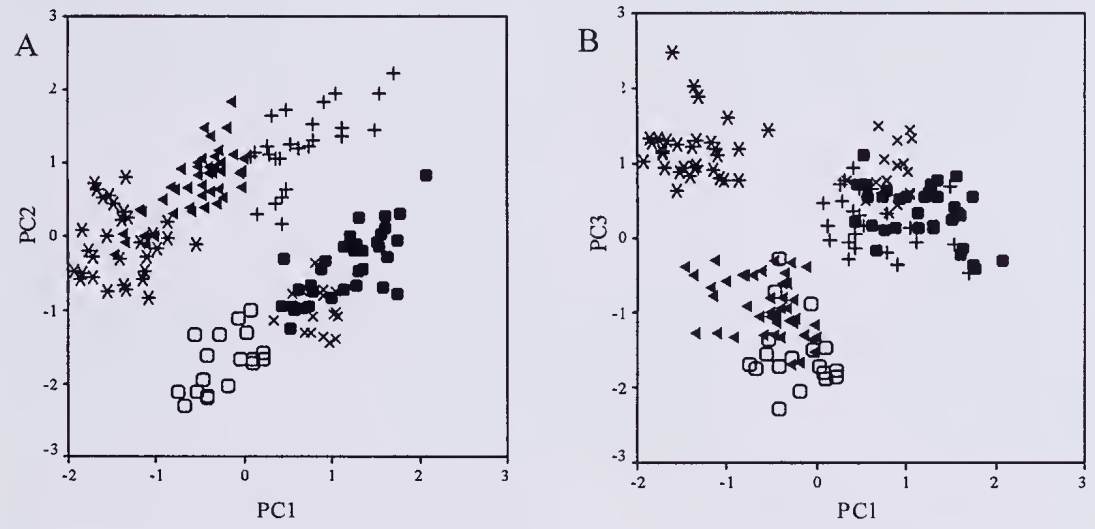

FIG. 30A-B. Scatter plots of first three axes of principal component analysis using 18 natural log/z-score transformed metric variables for *Longidigitis* species. + *L. maccullochii*; ◀ *L. utcheei*; × *L. hopevalensis*; ✶ *L. gracilis*; ○ *L. robustus*; ● *L. auripontiformis*.

Analysis of *Helicirrus* species identified three components, after the removal of three characters: DB2, H1 and H5. The three components accounted for 85.8% of the explained variance. PC1 accounted for 50.8%, PC2 accounted for 29.4% and PC3 accounted for 5.6%. The scatter plot combination of PC1 and PC2 clearly separated *H. megaloanchor*, *H. splendidae* and *H. maccullochii* (Fig. 29A) while the combination of PC1 and PC3 clearly separated *H. marjoriaea*, *H. gertrudaea* and *H. mcivori* (Fig. 29B). Dorsal anchor characters dominated the first component, while ventral anchor measurements dominated the second component and H6-7 and VB2 had highest correlation with PC3 (Table 11).

TABLE 9. Principal component correlation between natural log/z-score transformed variables and principal component functions for all species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance accounted for. * Largest absolute correlation between each variable and any principal component.

	Component			
	1	2	3	4
	(48.3%)	(22.3%)	(7.9%)	(5.9%)
H4	*.884	-.154	.305	-.100
H3	*.859	.163	.256	-.149
DB3	*.847	-.164	.119	.230
H2	*.821	.204	.271	-.262
DA2	*.819	-.514	-.118	.072
DB1	*.805	.005	.400	.213
H6	*.805	.247	.113	-.360
DA4	*.797	-.430	-.287	.150
DA5	*.772	-.354	-.112	.121
DA3	*.751	-.455	-.372	.086
DA1	*.718	-.476	-.031	.143
H7	*.698	.096	.321	-.513
VA5	*.680	.292	-.269	-.158
DA6	*.668	-.520	-.029	.260
VA2	*.661	.549	-.440	-.040
VA3	.409	*.782	-.351	.019
VA4	.492	*.763	-.294	.006
VA6	.231	*.737	-.124	.125
VB1	.423	*.732	.116	.400
VB2	.049	*.587	.530	.490

Principal component analysis identified four components for the *Longidigitis* species after the removal of six variables: VA1, VA6, DB2-3, H1 and H5. The four components accounted for 83.3% of the explained variance. PC1 accounted for 51.3%, PC2 accounted for 14.5%, PC3 accounted for 10.7% and PC4 accounted for 6.8%. The scatter plot combination of PC1 and PC2 separated *L. maccullochii*, *L. robustus*, *L. auripontiformis* and *L. gracilis*, with *L. utcheei* slightly overlapping *L. gracilis* and *L. hopevalensis* partially overlapping *L. auripontiformis* (Fig. 30A). The combination of PC1 and PC3 clearly separated *L. gracilis*, *L. utcheei* and *L. maccullochii* from each other while *L. auripontiformis*, *L. maccullochii* and *L. hopevalensis* overlapped and *L. utcheei* and *L. robustus* overlapped (Fig 30B). *Longidigitis auripontiformis* and *L. hopevalensis* clearly separated on PC4 (not shown). Dorsal and ventral anchor characters dominated component PC1, while hook measurements dominated PC2. Ventral bar characters dominated PC3 and dorsal bar character DB1 dominated PC4 (Table 12).

TABLE 10. Principal component correlation between natural log/z-score transformed variables and principal component functions for *Recurvatus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance accounted for. * Largest absolute correlation between each variable and any principal component.

	Component			
	1	2	3	4
	(39.8%)	(22.4%)	(16.4%)	(7.2%)
H2	* .942	.157	-.034	.000
H7	* .934	.189	-.030	-.003
H4	* .888	.268	.072	.014
VB1	*-.794	.107	.311	.083
DA3	*-.792	.488	.006	.068
DA4	*-.781	.510	.090	.033
H3	* .712	.311	.368	-.059
H6	* .617	.579	.09	-.123
VA1	*-.544	-.078	-.451	-.444
VA2	-.115	*.857	-.076	-.206
DA2	-.346	*.781	-.193	.171
VA5	.399	*.661	.156	-.324
VA4	-.522	*.600	.222	-.312
DA1	-.022	.330	*-.791	.268
VB2	-.370	.040	* .660	.381
DA5	.248	.510	-.153	*.653

Principal component analysis identified four components for the *Iliocirrus* species after the removal of nine variables: DA1, DA6, VA1, VA6, DB1-3, H1 and H5 (Table 13). The four components accounted for 79.3% of the explained variance. PC1 accounted for 37.5%, PC2 accounted for 22.2%, PC3 accounted for 12.5% and PC4 accounted for 7.2%. Examination of scatter plot combination of PC1 and PC2 identified the separation of *I. mazlini*, *I. rossi* and *I. iliocirrus* from each other, while *I. ornatusi* overlapped *I. mazlini* and *I. trifasciatae* and slightly overlapped *I. rossi* and *I. iliocirrus* (Fig. 31A). The combination of PC1 and PC3 clearly separated *I. mazlini* from *I. ornatusi* while *I. trifasciatae* slightly overlapped *I. rossi* and *I. iliocirrus* (Fig. 31B). A combination of dorsal and ventral anchor and hook characters dominated the first

TABLE 11. Principal component correlation between natural log/z-score transformed variables and principal component functions for *Helicirrus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance accounted for. * Largest absolute correlation between each variable and any principal component.

	Component		
	1	2	3
	(50.8%)	(29.4%)	(5.6%)
H4	*.972	.052	-.042
DB1	*.961	.113	-.039
H3	*.931	.164	-.037
DB3	*.929	.051	.008
DA2	*.910	-.308	.087
H2	*.887	.220	-.234
DA4	*.886	-.185	.181
DA5	*.850	-.065	.136
DA3	*.847	-.279	.129
DA1	*.833	-.114	.231
DA6	*.765	-.471	.207
H7	*.743	.077	-.552
H6	*.726	.322	-.512
VA1	*.612	.602	.234
VA2	.012	*.946	-.095
VA6	-.236	*.922	.104
VA4	-.228	*.893	.005
VA3	-.334	*.883	.006
VB1	.256	*.869	.264
VA5	.272	*.804	-.215
VB2	.362	*.665	.433

component, while hook characters dominated the second component. Ventral bar character VB2 and dorsal anchor character DA5 correlated highest with PC3.

DISCRIMINANT FUNCTION ANALYSIS. Stepwise analysis of the 4 genera combined with parasite species grouped into genera, identified the 3 characters, DB3 and DA5 and H1, not fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$) and were removed from the final analysis. The first function (F1) accounted for 76.1%, F2 for 18.9% and F3 for 5.0% of total variance. Examination of scatter plot of F1 and F2 separated *Helicirrus*, *Longidigitis* and *Iliocirrus* using F1 characters (Fig. 32A). Characters of F1 and F2 do not separate *Recurvatus* and *Helicirrus*. *Recurvatus* separates from the other 3 genera using F3 characters; however, *Helicirrus*, *Iliocirrus* and *Longidigitis* do not separate from each other (Fig.

TABLE 12. Principal component correlation between log/z-score transformed variables and principal component functions for *Longidigitis* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained. * Largest absolute correlation between each variable and any principal component.

	Component			
	1	2	3	4
	(51.3%)	(14.5%)	(10.7%)	(6.8%)
DA2	*.958	-.195	-.033	-.005
VA2	*.950	.013	.003	-.123
DA4	*.943	-.149	.078	-.035
DA3	*.941	-.159	.0265	-.0621
VA4	*.937	.094	.122	-.127
VA3	*.897	.049	.126	-.024
DA1	*.806	-.299	.113	-.242
VA5	*.790	-.158	-.279	-.105
H2	*.750	.494	-.005	.005
DA5	*.699	-.505	-.213	.090
DA6	*.676	-.502	.093	.073
H7	*.643	.521	-.260	-.057
H3	.284	*.704	-.481	.090
H4	.402	*.695	.300	-.252
H6	.496	*.511	-.278	.459
VB2	-.104	.355	*.851	-.087
VB1	.415	.053	*.734	.363
DB1	.289	-.111	.088	*.828

32B). All functions were significantly different using Wilks' λ ($p<0.001$). The characters, VA2 and DB2 had the highest correlation with F1, while DA3, VB1-2, VA4, VA6 and DA3-4 had the highest correlation with F2 and F3 had highest correlation with hook characters H2-4, H7, dorsal anchor characters DA1-2, DA6 and ventral anchor characters VA1 and VA5 (see Table 14). The functions were not dominated by a set of variables from any one morphological character i.e. anchors, bars or hooks, but a mixture of variables from each. All functions were significantly different using Wilks' λ ($p<0.001$). All eigenvalues were positive except DA3-4 indicating a size difference in the characters between genera.

Analysis of all 20 species together, identified all variables fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$). The first function accounted for 54.8% of the explained variance and uniquely correlated with DB2. F2 accounted for 22.8% of variance and

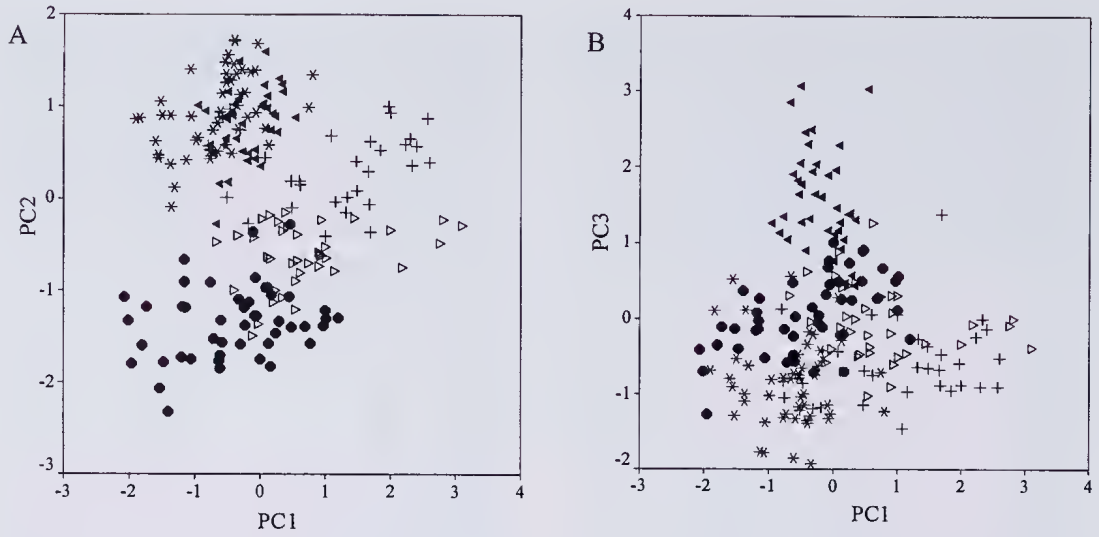

FIG. 31A-B. Scatter plots of first three axes of principal component analysis using 13 natural log/z-score transformed metric variables for *Iliocirrus* species; ▷ *I. trifasciatae*; + *I. rossi*; ✶ *I. ornatusi*; ◀ *I. mazlini*; ● *I. iliocirrus*.

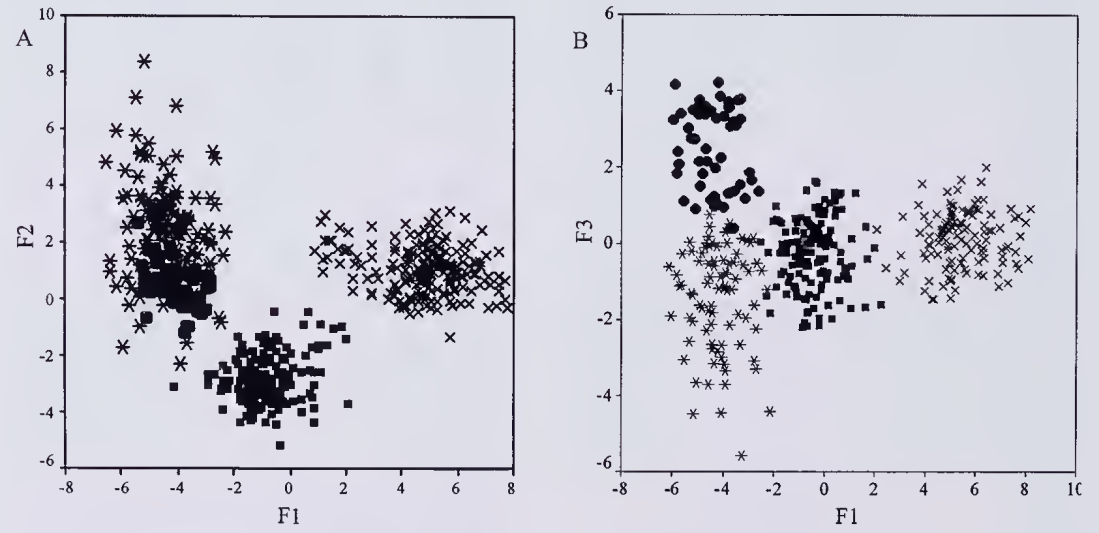

FIG. 32A-B. Scatter plots of first three axes of discriminant analysis for using 21 natural log/z-score transformed variables. Specimens entered as genera; × *Iliocirrus*; ■ *Longidigitis*; ✶*Helicirrus*; ● *Recurvatus*.

characters H4 and DA2 had highest correlation. F3 accounted for 5.5% of variance and correlated highest with ventral and dorsal anchor characters (Table 15). The first 17 functions were significantly different using Wilks' λ ($p<0.001$).

Analysis of *Recurvatus* identified 19 variables not fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$) (Table 16). Most of these rejected variables were anchor and bar measurements. The remaining five variables, hook characters H1, H2, H7, VB1 and VA4, clearly separated *R. signiferi* and *R. chelatus* (not shown). The low number of species in the analysis can explain the low number of characters used.

TABLE 13. Principal component correlation between natural log/z-score transformed variables and principal component functions for *Iliocirrus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained. * Largest absolute correlation between each variable and any principal component

	Component			
	1	2	3	4
	(37.5%)	(22.2%)	(12.5%)	(7.2%)
VA2	*.769	.456	.247	.044
VA4	*.709	.211	.475	-.079
H2	*.689	-.148	.456	.113
VA5	*.680	.161	.102	.452
H7	*.666	-.614	-.007	.128
DA4	*.661	.474	-.394	-.258
DA3	*.660	.373	-.264	-.458
H3	*.652	-.587	.073	-.015
DA2	*.649	.445	-.522	-.070
VA3	*.628	.194	.442	-.370
H6	.551	*-.756	-.054	.038
H4	.607	*-.721	-.109	-.040
VB1	.310	* .633	.154	.455
VB2	-.320	.393	* .570	.027
DA5	.408	.236	*-.558	.452

Analysis of species of *Helicirrus* identified 4 variables DA2, DA6, H1, and H5 not fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$). The first 3 functions accounted for 96.6% of the total explained variance. Function F1 accounted for 74.8%, F2 for 21.9% and F3 for 4.0% of the explained variance. Examination of the combined functions F1 and F2 scatter plot shows 3 distinct clusters. Characters of F1 and F2 separate *H. megaloanchor* from all other species, *H. splendidae* and *H. maccullochii* from all other species and *H. mcivori*, *H. gertrudaea* and *H. marjoriaea* from all other species (Fig. 33A). Function F1 and F2 characters do not clearly separate *H. splendidae* from *H. maccullochii* or *H. mcivori*, *H. gertrudaea* and *H. marjoriaea* from each other. Characters of F3 clearly separate *H. splendidae* from *H. maccullochii*, and *H. mcivori*, *H. marjoriaea* and *H. gertrudaea* from each other (Fig. 33B). Dorsal bar characters DB1, DB3 and H4 have highest correlation with F1, F2 correlates highest with ventral anchor characters and F3 correlates highest with characters VA5, VB2, H6 and DA1 (Table 17).

Analysis of species of *Longidigitis* identified the 3 characters H1, VA5-6 not fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$). The first 3 functions account for 89.2% of the total explained variance. Function F1 accounted for 48.5%, F2 accounted for 28.9% and F3 accounted for 11.8% of the variance. Function F1 characters separate *L. utcheei*, *L. maccullochii* and *L. gracilis* from *L. auripontiformis*, *L. robustus* and *L. hopevalensis* while F2 characters separate *L. auripontiformis*, *L. hopevalensis* and *L. robustus* from each other (Fig. 34A). Function F1 and F2 characters do not clearly separate *L. gracilis*, *L. maccullochii* or *L. utcheei* from each other. Function F3 characters separate *L. gracilis* from *L. utcheei* and *L. maccullochii* (Fig. 34B), while *L. maccullochii* and *L. utcheei* separate by using F4 characters (not shown). Dorsal anchor characters dominate F1, ventral anchor characters dominate F2, hook characters dominate F3, and ventral bar characters dominate F4 (Table 18).

TABLE 14. Pooled within-groups correlations between natural log/z-score transformed variables and standardised canonical discriminant functions for generic level grouping. Specimens entered as genera. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained * Largest absolute correlation between each variable and any discriminant function. # Variable not used in the analysis.

	Function		
	1	2	3
	(76.1%)	(18.9%)	(5.0%)
DB2	* .500	.213	.073
VA2	* .205	.028	.040
VB2	-.012	* .440	.193
DA3	.154	*-.410	.177
VB1	.153	* .408	.134
DA4	.144	*-.348	.263
VA6	.075	* .298	.147
VA4	.227	* .267	-.058
H5	.122	* .252	-.012
VA3	.189	* .245	-.113
H1#	.028	* .129	.071
H2	.169	.091	*.605
H7	.101	.049	*.495
DA1	.068	-.280	*.453
H4	.144	-.077	*.411
DB1	.113	.088	*.402
DA5#	.085	-.164	*.389
DA2	.144	-.348	*.385
H6	.264	.050	*.375
VA5	.140	-.064	*.348
DB3#	.112	-.115	*.347
H3	.241	.088	*.309
DA6	.070	-.168	*.269
VA1	.047	-.156	*.231

TABLE 15. Pooled within-group correlations between natural log/z-score transformed variables and standardised canonical discriminant functions at species level grouping. Specimens entered as species groups. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. Only functions with highest correlations shown. (%) percent total variance explained. * Largest absolute correlation between each variable and any discriminant function.

	Function											
	1	2	4	5	6	7	9	10	11	14	15	17
%	54.8	22.8	5.5	2.9	1.9	1.5	1.2					
DB2	*.93	-.07	-.07	.08	-.10	.11	-.05	-.04	-.01	.01	.06	-.00
H4	.24	*.64	.08	-.23	-.01	-.11	.09	.34	-.02	.05	-.18	-.04
DA2	.08	*.54	.46	.03	.15	.29	-.12	.14	.22	.01	-.21	-.12
VA2	.13	.05	*.68	-.26	-.07	.14	-.14	-.05	-.07	.02	-.03	.12
VA3	.13	-.10	*.50	-.20	.15	.21	-.04	.21	.14	.08	.01	-.14
VA4	.17	-.08	*.50	-.19	.15	.26	.09	.12	-.17	.12	.13	-.08
DA3	.05	.34	*.47	-.05	.03	.19	.02	.23	.06	.10	.34	-.02
DA4	.05	.33	*.43	.02	.01	.16	-.02	.22	.09	.41	.16	-.03
VB2	.06	-.08	-.18	*.49	-.04	.04	-.15	.05	.38	.21	-.06	.08
H7	.06	.19	-.04	*-.36	.14	.33	-.05	.19	-.07	.22	.05	.24
H3	.21	.26	.10	-.27	*.63	-.09	.03	-.03	.00	.19	-.19	.16
H2	.11	.21	.06	-.22	.19	*.56	-.29	.02	.09	.04	.21	-.06
DA6	.02	.25	.14	.16	.25	*.37	.23	.31	-.21	-.04	.04	.21
VB1	.15	-.06	.23	.31	.17	.01	*-.45	.42	-.17	.04	.07	.13
H6	.14	.14	.14	-.40	.30	-.09	-.08	*.53	.09	-.02	.13	.08
VA6	.06	-.10	.27	.03	.06	.01	.32	*.36	-.03	.18	-.17	-.23
VA1	.02	.12	.21	.10	-.13	-.23	-.02	-.07	*.40	-.28	.11	.27
VA5	.06	.10	.34	-.15	-.07	-.04	.03	-.11	-.09	*.45	-.01	-.23
DA5	.02	.20	.24	-.01	.20	.20	.10	.06	.19	*.36	.01	.18
H5	.06	-.03	.15	.07	.19	.08	.14	.04	-.25	-.13	*-.41	.19
DB3	.08	.24	.27	.15	.14	-.05	.34	-.07	.08	-.16	*.38	-.07
DA1	.01	.23	.29	.05	-.16	.21	.30	.13	.28	-.02	.03	*.38
H1	.03	-.05	.09	-.09	.137	.24	.18	.25	.04	-.29	-.15	*-.36
DB1	.10	.23	.06	.18	.39	-.11	-.18	.10	-.24	.07	.22	-.07

TABLE 16. Pooled within-group correlations between natural log/z-score transformed variables and standardised canonical discriminant functions for *Recurvatus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. # Variable not used in the analysis.

	Function
	1
H2	.548
H7	.492
H3#	.309
H6#	.284
DB3#	-.243
H4#	.206
VA6#	.202
VA5#	.196
VB1	-.196
DB1#	.166
VA4	-.091
VA3#	-.078
DA6#	.071
VA2#	-.056
H1	.055
VA1#	.046
DA2#	.032
DA3#	.023
VB2#	.009
DA1#	-.006
H5#	-.006
DA4#	.006
DA5#	.003

Analysis of species of *Iliocirrus* identified 12 variables not fitting the selection criteria of F to enter ($p<0.05$) and F to remove ($p<0.01$). The first 3 functions account for 91.4% of total explained variance. Function F1 accounted for 58.4%, F2 for 18.5% and F3 for 14.5% of the variance. Examination of characters for F1 and F2 scatter plot clearly separates *I. ornatusi*, *I. mazlini* and *I. iliocirrus* from each other. *Iliocirrus rossi* and *I. trifasciatae* cluster together with partial overlapping of *I. iliocirrus* (Fig. 35A). Function F3 characters separate *I. rossi* from *I. iliocirrus* and *I. trifasciatae* (Fig. 35B), while F4 characters separate *I. trifasciatae* from *I. rossi* and *I. iliocirrus* (Fig. 35C). Hook characters dominate F1; characters VB2, DA5 and H5 dominate F2. Dorsal and ventral bar characters are correlated highest with F3 and characters H1-2 and DB3 correlate highest with F4 (Table 19).

CROSS VALIDATION. Using the within-group covariance matrix and weighted for sample size with parasites entered as genera, cross-validation correctly classified 97.1% of the 591 specimens measured (Table 20). For *Recurvatus*, 10.8% of specimens mis-classified as *Helicirrus*, while for specimens of *Helicirrus* 3.7% classified as *Recurvatus* and 2.2% classified as *Longidigitis*. All specimens of *Longidigitis* and *Iliocirrus* classified correctly. This high level of correctly classified specimens indicates that combinations of haptoral morphometric variables are able to identify the genera defined by copulatory apparatus morphology. When all parasites were analysed together and entered as species, 99.5% of specimens classified into their correct genus. Specimens mis-classified were not identified as species within their own genus but across genera. Two specimens (13.3%) of *H. gertrudaea* classified as *R. signiferi* while one specimen of *H. mcivori* classified as *L. gracilis*.

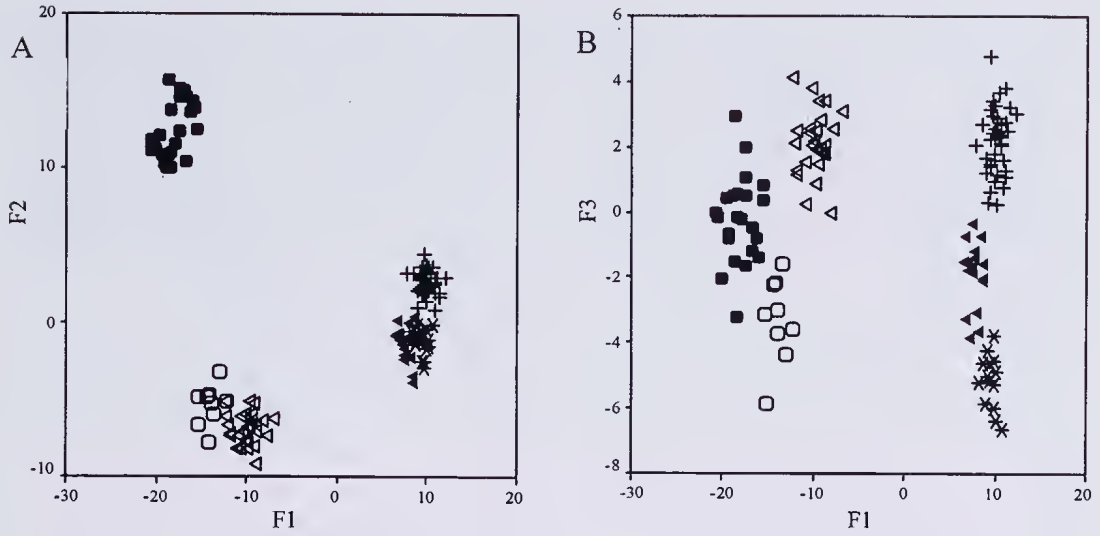

FIG. 33A-B. Scatter plots of first three axes of discriminant functions using 18 natural log/z-score transformed metric variables for *Helicirrus* species. ◁ *H. splendidae*; ● *H. megaloanchor*; ◀ *H. mcivori*; + *H. marjoriaea*; ○ *H. maccullochii*; ✶ *H. gertrudaea*.

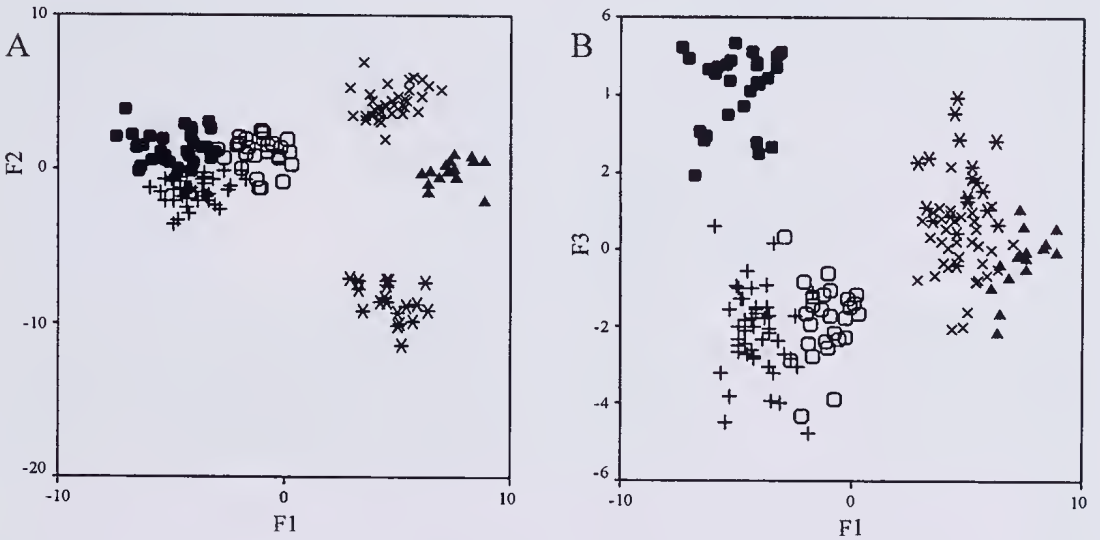

FIG. 34A-B. Scatter plots of first three axes of discriminant functions using 20 natural log/z-score transformed metric variables for *Longidigitis* species. ○ *L. utcheei*; + *L. maccullochii*; ▲ *L. hopevalensis*; ● *L. gracilis*; ✶ *L. robustus*; × *L. auripontiformis*.

DISCUSSION

Helicirrus species have the greatest haptoral sclerite variation while *Iliocirrus* species have the least. For *Iliocirrus*, *I. trifasciatae* is least discernable from other species of the genus, especially from *I. rossi* and *I. mazlini*, based on haptoral sclerite variation; however, *I. trifasciatae* is the most different from all species of *Iliocirrus*, based on copulatory apparatus morphology. Species of *Longidigitis* could be separated into two groups, *L. gracilis*, *L. maccullochii*, *L. utcheei* and *L. auripontiformis*, *L. hopevalensis* and *L. robustus*, based on haptoral sclerite variation. The '*gracilis*' group shows consistent similarities in haptoral and copulum structures

TABLE 17. Pooled within-groups correlations between natural log/z-score transformed variables and standardised canonical discriminant functions for *Helicirrus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained. * Largest absolute correlation between each variable and any discriminant function. # Variable not used in the analysis.

	Function				
	1	2	3	4	5
	(74.8%)	(17.8%)	(4.0%)	(2.1%)	(1.2%)
H4	*.688	.286	-.129	-.169	.060
DB1	*.316	.175	.073	.244	-.038
DB3	*.233	.110	.053	.004	.196
VA2	-.046	*.552	-.345	.024	.090
VA6	-.121	*.542	-.045	.038	.285
VA3	-.129	*.388	-.117	.159	.383
VB1	.011	*.366	.122	-.013	.013
VA1	.086	*.260	.060	-.132	.004
H5#	-.052	*.258	-.004	-.093	.010
VB2	.044	.340	* .420	.095	-.264
VA5	.026	.305	*-.346	-.038	.061
H6	.124	.137	*-.278	.219	-.168
DA1	.166	.039	* .245	-.108	-.025
DA2#	.181	.038	* .198	-.196	.107
DA6#	.101	.091	* .144	.015	-.031
H7	.150	.052	-.309	* .486	-.132
H2	.196	.144	-.146	* .385	.162
DA5	.135	.026	.095	* .205	-.128
H1#	.046	.124	.081	*-.148	.012
DA3	.167	-.074	.046	-.107	*.385
VA4	-.092	.364	-.079	.230	*.378
DA4	.176	-.030	.092	-.116	*.372
H3	.236	.153	.062	.249	*.274

TABLE 18. Pooled within-groups correlations between natural log/z-score transformed variables and standardised canonical discriminant functions for *Longidigitis* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained. * Largest absolute correlation between each variable and any discriminant function. # This variable not used in the analysis.

	Function				
	1	2	3	4	5
	(48.5%)	(28.9%)	(11.8%)	(7.1%)	(3.6%)
DA2	*.452	.167	-.328	.040	-.356
DA3	*.416	.223	-.338	.021	-.389
DA1	*.340	.235	-.124	-.199	-.153
DA5	*.330	-.075	-.075	-.084	-.027
DA6	*.291	.060	.111	-.046	-.268
DB3	*.283	.135	.003	-.057	.275
H4	-.088	*.451	-.266	-.009	-.392
VA2	.399	*.274	-.587	.118	-.174
VA3	.337	*.233	-.504	.314	-.038
VA4	.324	*.322	-.478	.135	-.232
H7	.037	.106	*-.402	-.024	-.281
H3	-.078	-.024	*-.393	.019	-.304
H6	.026	-.041	*-.363	.358	-.357
H1	.171	.021	*-.187	.052	.113
VB1	.143	.239	.140	*.713	.015
VB2	-.118	.357	.200	*.386	.370
DA4	.384	.238	-.244	.044	*-.481
H2#	.029	.175	-.287	.158	*-.292
VA5#	.208	.032	-.119	-.015	*-.287
H5	.214	-.060	.028	-.014	*-.250
VA6#	.120	.102	-.085	-.102	*-.240
DB1	.065	-.032	.096	.120	*-.173
VA1	.148	-.023	.083	.140	*-.150
DA2	.452	.167	-.328	.040	*-.356

and is clustered together in both PCA and DFA analyses. *Longidigitis auripontiformis* and *L. hopevalensis* have similar haptoral sclerite morphologies but are easily distinguished by the differences in copulatory apparatus morphology.

Two haptor morphologies were identified in species of *Helicirrus*. Well-developed dorsal anchors, dorsal bar and elongated hooks are present in *H. mcivori*, *H. gertrudaea* and *H. marjoriaea*. Highly reduced dorsal anchors, dorsal bar and hooks are found in *H. splendidae*, *H. maccullochii* and *H. megaloanchor*. This may be associated with the attachment site on the host. All *Longidigitis*, *Iliocirrus* and *Recurvatus* species attach to the gill filaments while *H. splendidae* and *H. maccullochii* most often attach between the gill raker spines (unpublished data). A similar reduction can be also found in gyrodactylids (pers. obs.). It is not known if this is related to their attachment to a different, more simplified, part of the gill structure. The well-developed haptoral sclerite structures of the *Longidigitis*, *Iliocirrus* and *Recurvatus* species and *Helicirrus mcivori*, *H. gertrudaea* and *H. marjoriae* may be an adaptation to the complexity of the soft gill tissue which may require more developed ventral and dorsal sclerites. *Helicirrus megaloanchor* has reduced hooks and highly reduced dorsal bar and anchors. However this species attaches to the gill filaments and not between the gill raker spines. This species has extremely large ventral anchors, which may be an adaptation for attachment to the soft gill tissue.

Both haptoral and copulum structure are recognised as important in defining the genera, and there is congruence between the two approaches. The parasite species were grouped into genera based on copulatory apparatus morphology. Principal component analysis and DFA clearly identified a number of clusters, recognised *a posteriori* as the parasite genera and species described using morphology. Thus, the

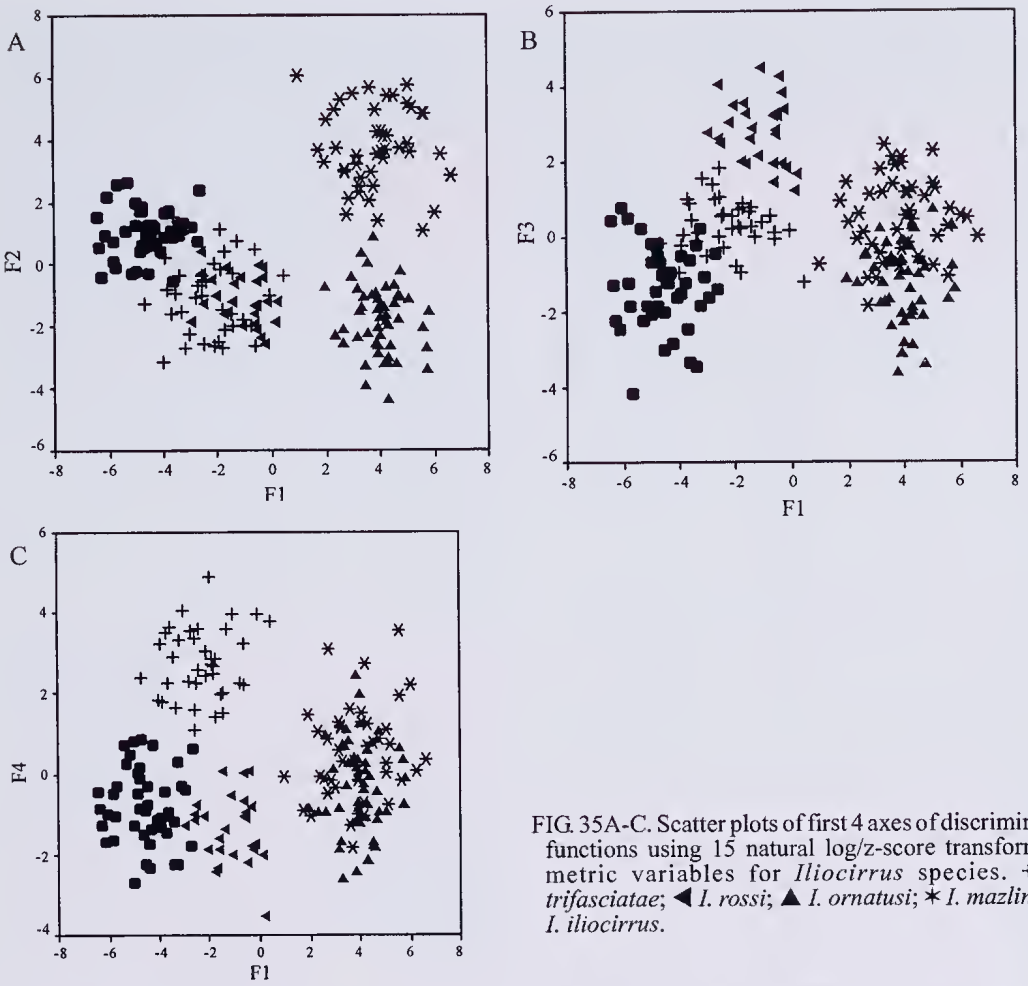

FIG. 35A-C. Scatter plots of first 4 axes of discriminant functions using 15 natural log/z-score transformed metric variables for *Iliocirrus* species. + *I. trifasciatae*; ◀ *I. rossi*; ▲ *I. ornatusi*; ✶ *I. mazlini*; ● *I. iliocirrus*.

genera and species were validated using only morphometric haptoral characters. Reproductive and to a lesser extent haptoral morphology appears the most natural taxonomically for the species assigned to *Helicirrus*, *Recurvatus*, *Iliocirrus* and *Longidigitis*. Haptoral sclerite morphology groupings can also reflect generic groupings based on copulatory apparatus structure. However, no single or set of morphological characters are unique to each genus. Separation of each genus is by a set of broadly recognised morphometric variations between characters defined by PCA and DFA.

Principal component analysis and DFA are used as a means of data reduction by reducing a large number of character variables into a much smaller number of variables called principal components and discriminant functions respectively and are often graphically represented as two or three dimensional scatter plots. These methods also identify which characters have the highest correlation for each new variable. The two, however, use different approaches. Principal component analysis extracts new variables based solely on the correlation within and between variances of characters without any *a priori* grouping of the character variants. Analysis of the 20 species in this study using PCA identified a maximum of five new variables. Discriminant function analysis considers variables to be correlated and is designed to present contrasting (as opposed to independent) patterns of variation. Discriminant function analysis uses *a posteriori* approach to produce a set of new variables that best maximises differences between the predetermined groups using correlation of variances within and between characters. The number of new variables defined for discriminant analysis is (n-1), where

TABLE 19. Pooled within-group correlations between natural log/z-score transformed discriminating variables and standardised canonical discriminant functions for *Iliocirrus* species. Variables ordered by absolute size of correlation within function. DA1-6, dorsal anchor; VA1-6, ventral anchor; DB1-3, dorsal bar; VA1-2, ventral bar; H1-7, hook length. (%) percent total variance explained. * Largest absolute correlation between each variable and any discriminant function. # This variable not used in the analysis.

	Function			
	1	2	3	4
	(58.4%)	(18.5%)	(14.5%)	(8.6%)
H4	*-.514	-.050	.299	.056
H6	*-.387	-.021	.011	.234
H3	*-.251	.086	.181	-.023
VA6#	*-.163	-.099	.001	.108
VB2	.201	* .437	-.200	-.252
DA5	.041	*-.338	.133	.025
H5	.093	* .209	-.018	.179
DA6#	-.092	*-.202	.199	.195
DB2	-.033	.110	* .572	.004
VA3	-.009	.197	* .557	.076
VA4	.007	.227	* .456	.206
VA2#	.060	.092	* .424	.153
DA4	.072	-.283	* .417	-.147
DA2	.082	-.378	* .403	-.103
DA3#	-.020	-.123	* .367	-.104
VB1	.255	-.060	* .280	.222
DB1#	-.009	-.062	* .244	.201
VA1#	.008	-.071	*-.142	-.051
DA1#	.069	.022	* .122	-.076
H2	-.070	.166	.318	*.478
DB3	-.023	.019	-.003	*.317
H1	-.082	.059	.105	*.247
H7#	-.165	.049	.212	*.221
VA5#	-.018	.050	.026	*.052

n is the number of predefined groups. Correlation of explained variance is accounted most in the first three discriminant functions and the last few usually produce a non-significant difference in the centroid means of clusters.

Discriminant function analysis differs from PCA in that parasite specimens are assigned *a priori* to groups and then scatter plots are used to assess if these groups are valid. Character variables are also identified which best reflect these *a priori* groups. However, the characters chosen change depending on *a priori* sample grouping. This method was able to identify morphological characters that define the four genera. This is not possible using PCA if clusters are not clearly defined. The advantage of DFA over PCA in taxonomy is that when species have been identified using morphometric variables, measured unknown specimens and especially cryptic species can be identified using cross-validation. Discriminant function analysis identified sets of characters that were not included in the final analysis at the various levels of investigation. These character sets indicate redundancy of information in the data and are not necessary in the analysis. The sets of characters, however, change at the various levels of analysis limiting *a priori* selection of characters for removal. Taxonomists often use alternative methods such as K-cluster or hierarchical cluster analysis for the same purpose (Anderberg, 1973). However, these methods do not identify the most useful characters for the separation of clusters but rely on *a priori* selection, usually obtained by multivariate analysis.

Multivariate analysis identified significant differences within character means between species and the species descriptions use these differences. An example is the length relationships among hooks among and between species. However, different MANOVA methods often identify a varying number of significant differences. This was shown with the comparison of the Scheffé and Tukey's HSD test multiple range tests ($p< 0.01$). For example, for *H. marjoriaea* and *H. mcivori*, 11 significantly different characters were identified using Scheffé test while 17 were identified using Tukey's HSD test. This indicates that Scheffé test is more conservative in identifying significant character differences than the Tukey's HSD test. The true number of differences lies somewhere between these two extremes for $\propto$=0.05-0.01.

TABLE 20. Generic level grouping cross-validation. Each case is classified by the functions derived from all cases other than that case. Specimens entered as genus groups. 97.1% of cross-validated grouped cases correctly classified.

		Predicted Group Membership				Total
	Genus	*Recurvatus*	*Helicirrus*	*Longidigitis*	*Iliocirrus*	591
Count	*Recurvatus*	66	8	0	0	74
%	*Helicirrus*	5	125	3	0	134
	Longidigitis	0	0	174	0	174
	Iliocirrus	0	0	0	209	209
	Recurvatus	89.2	10.8	.0	.0	100.0
	Helicirrus	3.7	93.3	2.2	.0	100.0
	Longidigitis	.0	.0	100.0	.0	100.0
	Iliocirrus	.0	.0	.0	100.0	100.0

A much better understanding is needed of the diversity of morphological and morphometric variation of the haptoral structures and possible correlations to the genera. The same understanding is also needed for the reproductive system. The species of *Iliocirus* show little easily identifiable copulatory apparatus or haptoral morphological variation and are difficult to recognise visually, but are easily identified, using morphometric analysis of haptoral sclerite variability. This lack of morphological variation also has implications for cladistic studies, which traditionally use morphological characters. Methodologies have been developed for cladistic analysis of morphometric variation (Archie, 1985; Baum, 1988). However, cladistic studies have not been attempted on haptoral variation of monogenean taxa, e.g. Gyrodactylidae, although it is a well studied group.

Comparison of the four monogenean parasites described previously from other atherinid species identified extremely elongated hooks in *Atherinicus cornutus*, *Ancyrocephalus atherinae*, *Diversohamulus tricuspidatus and Ancyrocephalus littoralis*. However, a gonadal bar is present in *A. cornutus*, which is absent in species of the genera *Longidigitis*, *Iliocirrus*, *Recurvatus* and *Helicirrus* as well as all other species of genera infesting atheriniform fishes. *Diversohamulus tricuspidatus* has a haptoral sclerite complex similar to *L. megaloanchor* with similar increase in length of hooks, large ventral anchors and bar and highly reduced dorsal bar and anchors. However the former species (as well as *A. atherinae* and *A. littoralis*) differs from species in the four new genera in the copulatory apparatus structure. The copulatory apparatus of *D. tricuspidatus* does not resemble any of the four types described earlier but consists of a straight tubiform copulum shaft and an accessory piece, which has a few distal ramifications and is attached to the proximal surface of the copulum base. The copulatory apparatus structure of *A. cornutus* has similarities to the Type III form found in *Longidigitis* species consisting of a single recurved loop. However the copulum shaft is directed anteriorly not dextrally and the accessory piece is different. The vaginal opening in *A. cornutus* and *D. tricuspidatus* is ventral and dextral in *A. atherinae* and *A. littoralis* while it is sinistral in species of *Longidigitis* and *Iliocirrus*.

KEY TO MONOGENEAN PARASITE GENERA OF AUSTRALIAN ATHERINIFORM FISHES

1. Copulum shaft coiled at distal end posterior to copulum base . . . . . *Helicirrus*
2. Copulum shaft single counter-clockwise coil (ventral view) encircling copulum base . . . . . *Recurvatus*
3. Copulum shaft comprises a single sinistral recurved loop . . . . . *Longidigitis*
4. Copulum shaft comprises two sinistral recurved loops . . . . . *Iliocirrus*

KEY TO SPECIES OF *HELICIRRUS*

1. Hooks reduced, H4 shorter than ventral anchor. 2
   Hooks elongated form, H4 always longer than ventral anchor. 4
2. Copulum shaft proximally expanded to form a chamber. 3
   Copulum shaft not expanded . . . . . *H. splendidae*
3. Ventral anchor extremely large dorsal anchor highly reduced. . . . . *H. megaloanchor*
   Ventral anchor slightly larger than dorsal anchor . . . . . *H. maccullochii*
4. Copulum shaft not expanded proximally 5
   Copulum shaft expanded proximally . . . . . *H. mcivori*
5. Copulum shaft highly coiled at distal end (30 coils) . . . . . *H. marjoriaea*
   Copulum shaft few coils (<10) . . . . . *H. gertrudaea*

KEY TO SPECIES OF *RECURVATUS*

1. Accessory piece large, claw shaped, hook H4 shaft similar thickness to H3 . . . . . *R. chelatus*
   Accessory piece not as above, hook H4 shaft much thinner than H3 . . . . . *R. signiferi*

KEY TO SPECIES OF *LONGIDIGITIS*

1. Notch present on posteromedial margin of dorsal bar . 2
   Notch absent on posteromedial margin of dorsal bar . . 4
2. Anchors with thickened roots . . . . . *L. robustus*
   Anchor roots not thickened. 3
3. Dorsal bar ear-shaped with membrane infill on anterior edge . . . . . *L. hopevalensis*
   Dorsal bar, not ear-shaped, without infill on anterior edge . . . . . *L. gracilis*
4. Dorsal bar ear-shaped, membrane infill on anterior edge present . . . . . *L. auripontiformis*

Dorsal bar not ear-shaped, without infill on anterior edge. . 5

5. Hooks H2 shorter than H1, H3 and H5 of similar length . . . . . *L. utcheei*
   Hooks H2 and H1 similar in length, H3 longer than H5 . . . . . *L. maccullochii*

KEY TO SPECIES OF *ILIOCIRRUS*

1. Hooks H1 and H5 similar in length. . . . . *I. mazlini*
   Hooks H1 much smaller in length than H5 2
2. Ventral bar with deep V-shaped notch on posterior medial edge . . . . . *I. ornatusi*
   Ventral bar without deep V-shaped notch on posterior medial edge 3
3. Hooks H3 and H5 similar size 4
   Hooks H3 longer than H5. . . . . *I. rossi*
4. Copulum shaft thin, recurved loops reduced . *I. trifasciatae*
   Copulum shaft thick, recurved loops well-developed . . . . . *I. iliocirrus*

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LITERATURE CITED

AFIFI & AZENI 1979. Statistical analysis. A computer oriented approach. 2nd edn. (Academic press, Inc.: Sydney).

ALLEN, G.R., MIDGLEY, S.H. & ALLEN, M. 2002. Field guide to the freshwater fishes of Australia. (Western Australian Museum: Perth).

ALLEN, G.R. & RENYAAN, S.J. 1998. Three new species of rainbowfishes (Melanotaeniidae) from Irian Jaya, Indonesia. Journal of Ichthyology and Aquatic Biology 3: 69-80.

ANDERBERG, M.R. 1973. Cluster analysis for applications (Academic Press: New York).

ARCHIE, J.W. 1985. Methods for coding variable morphological features for numerical taxonomic analysis. Systematic Zoology 34: 326-345.

BAUM, B.R. 1988. A simple procedure for establishing discrete characters from measurement data, applicable to cladistics. Taxon 37: 63-70.

BEVERLEY-BURTON, M. 1984. Guide to the parasites of fishes of Canada. Part 1. Pp. 5-209. In Margolis, L. & Kabata, Z. (eds) Monogenea and Turbellaria. Vol. 74, (Canadian Special Publication of Fisheries and Aquatic Sciences. Department of Fisheries and Oceans: Ottawa).

BEVERLEY-BURTON, M. & KLASSEN, G.J. 1990. New approaches to the systematics of the ancyrocephalid monogenea from Nearctic freshwater fishes. Journal of Parasitology 76: 1-21.

BEVERLEY-BURTON, M. & SURIANO, D.M. 1980a. *Cleidodiscus robustus* Mueller, 1934 (Monogenea: Ancyrocephalinae) from *Lepomis gibbosus* L. (Pisces: Centrarchidae) in Ontario, Canada: anatomy and systematic position. Canadian Journal of Zoology 58: 654-660.

1980b. *Haplocleidus dispar* (Mueller, 1936) and *Pterocleidus acer* (Mueller, 1936) (Monogenea: Ancyrocephalinae) from *Lepomis gibbosus* L. (Pisces: Centrarchidae) in Ontario, Canada: anatomy and systematic position. Canadian Journal of Zoology 58: 661-669.

BOEGER, W.A. & KRITSKY, D.C. 1988. Neotropical Monogenea. 12. Dactylogyridae from *Serrasalmus nattereri* (Cypriniformes: Serrasalmidae) and aspects of their morphological variation and distribution in the Brazilian Amazon. Proceedings of the Helminthological Society of Washington 55: 188-213.

BYCHOWSKY, B.E. & NAGIBINA, L.F. 1969. New genera of the monogenean subfamily Ancyrocephalinae (Dactylogyridae). [In Russian; Engl. sum.]. Parazitologiya 3: 518-527.

1978. The revision of Ancyrocephalinae Bychowsky, 1937 (Monogenoidea) [In Russian]. Parazitologiceskii Sbornik 28: 5-15.

DYER, B.S. & CHERNOFF, B. 1996. Phylogenetic relationships among atheriniform fishes (Teleostei: Atherinomorpha). Zoological Journal of the Linnaean Society 117: 1-69.

FLETCHER, A.S. & WHITTINGTON, I.D. 1998. A parasite-host checklist for Monogenea from freshwater fishes in Australia, with comments on biodiversity. Systematic Parasitology 41: 159-168.

GUSSEV, A.V. 1973. Freshwater Indian Monogenoidea. Principles of systematics, analysis of the world faunas and their evolution. Indian Journal of Helminthology 25 & 26: 1-241.

1978. Monogenoidea of freshwater fishes. Principals of systematics, analysis of world fauna and their evolution. Parazitologiccskii Sbornik 28: 96-198.

HUMASON, G.L. 1979. Animal tissue techniques. (W.H. Freeman and Co.: San Francisco).

JOHNSTON, T.H. & TIEGS, W.O. 1922. New gyrodactyloid trematodes from Australian fishes, together with a reclassification of the superfamily Gyrodactyloidea. Proceedings of the Linnaean Society of New South Wales 47: 83-131.

KLASSEN, G.J. 1991. Revision of *Haliotrema* species (Monogenea: Ancyrocephalidae) from Atlantic boxfishes (Tetraodontiformes; Ostraciinae): morphology, morphometrics and distribution. Canadian Journal of Zoology 69: 2523-2539.

KRITSKY, D.C., BOEGER, W.A. & THATCHER, V.E. 1985. Neotropical Monogenea. 7. Parasites of the Pirarucu, *Arapaima gigas* (Cuvier), with descriptions of two new species and redescription of *Dawestrema cycloancistrium* Price & Nowlan, 1967 (Dactylogyridae: Ancyrocephalinae). Proceedings of the Biological Society of Washington 98: 321-331.

MALMBERG, G. 1970. The excretory systems and the marginal hooks as a basis for the systematics of *Gyrodactylus* (Trematoda, Monogenea). Arkiv foer Zoologi Series 2, 23: 1-235.

MCGUIGAN, K.L. 2001. An addition to the rainbowfish (Melanotaeniidae) fauna of North Queensland. Memoirs of the Queensland Museum 46: 647-655.

MIZELLE, J.D. 1936. New species of trematodes from the gills of Illinois fishes. American Midland Naturalist 17: 785-806.

MIZELLE, J.D. & HUGHES, R.C. 1938. The North American fresh-water Tetraonchinae. American Midland Naturalist 20: 341-353.

PAPERNA, I. & KOHN, A. 1964. Report on monogenetic trematodes collected from East Mediterranean. Revista Brasileira de Biologia 24: 243-248.

PRICE, E.W. 1934. New monogenetic trematodes from marine fishes. Smithsonian Miscellaneous Collections 91: 1-3.

SHINN, A.P., KAY, J.W. & SOMMERVILLE, C. 2000. The use of statistical classifiers for the descrimination of species of the genus *Gyrodactylus* (Monogenea) parasitizing salmonids. Parasitology 120: 261-269.

SURIANO, D.M. & BEVERLEY-BURTON, M. 1982. *Aethycteron* n. g. (Monogenea: Ancyrocephalinae) from darters (Percidae: Etheostomatini) in Ontario, Canada with description of *A. caerulei* n. sp., *A. micropercae* n. sp. and *A. nigrae* n. sp. from *Etheostoma* spp. Canadian Journal of Zoology 60: 1397-1407.

YOUNG, P.C. 1968. Ten new species of *Haliotrema* (Monogenoidea: Dactylogyridae) from Australian fishes and a revision of the genus. Journal of Zoology, London 154: 412-475.

ZHANG, J.Y., YANG, T.B. & LIU, L. 2001. Monogeneans of Chinese marine fishes. (Agriculture Press: Beijing).

ZHUKOV, E.V. 1984. New species of monogeneans of the family Ancyrocephalidae from gills of *Atherina stipes* from the Gulf of Mexico. Parazitologiya 18: 59-62.

NORTHERLY RANGE EXTENSION FOR *CTENOTUS ARCANUS* (SQUMATA: SCINCIDAE) IN QUEENSLAND. *Memoirs of the Queensland Museum 49(2): 572. 2004:-* *Ctenotus arcanus* (Czechura & Wombey, 1982) belongs to a group of swift moving, diurnal skinks. Like most members of this genus, the species is characterised by a series of dark longitudinal stripes and upper lateral spots (Cogger, 2000). *C. arcanus* typically has a coppery-brown, dorsal surface with a pale-edged, dark vertebral stripe which reduces down to a line on the nape (Wilson & Swan, 2003). A pale coloured, narrow dorso-lateral stripe also extends from above the eye through to the tail (Czechura & Wombey, 1982). This stripe is usually bordered above by a narrow, black stripe and below by a much broader stripe, which encloses a series of well-defined, white dots (Wilson & Swan, 2003). A white mid-lateral line extends from the snout to the tail. The ventral surface is pale coloured with a bit of grey flecking on the edges. The limbs are reddish brown to olive in colour with small, dark stripes. Adults usually average 90mm snout-vent length (Cogger, 2000).

This species favours rocky, eucalypt dominated open forest and woodlands, heaths and the margins of wet sclerophyll forests (Czechura & Wombey, 1982). In Queensland, the species is known to occur from Kroombit Tops (24°21'59"S, 150°58'59"E) south to Burnett Gorge (28°18'47"S, 152°33'25"E) (EPAa, 2003). Wilson & Swan (2003) define the range for the species as continuing further south into northern New South Wales and they also documented a disjunct population around the Carnarvon Ranges in Central Queensland. The Carnarvon population was found on the Consuelo Tableland on the Mount Moffatt section of Carnarvon National Park (C. Eddie, QPWS pers. comm.). The Western Australian Museum's database (FaunaBase) contains records of *C. arcanus* from Kroombit Tops (24°21'59"S, 151°01'59"E) south to Boorook (28°45'00"S, 152°09'59"E) west to the Carnarvon's (24°54'59"S, 148°02'59"E) and east to Stradbroke (27°33'59"S, 153°25'59"E) and Fraser Islands (25°32'59"S, 153°01'59"E) (WAM, 2003).

In May 2003, a systematic fauna survey was conducted at Eungella National Park, Crediton State Forest and Homevale Resource Reserve. Vertebrate fauna were surveyed using a combination of Elliott, cage, pit fall and harp traps, bat triplines, spotlighting, active searches and bird censuses. The survey found a total of 167 vertebrate species including *C. arcanus*.

The species was caught in a pit trap at a site in Homevale Resource Reserve (21°20'30"S, 148°32'6"E) and at a site in Crediton State Forest (21°16'44"S, 148°31'24"E). The vegetation at the Homevale Resource Reserve site consisted of a mixed *Corymbia citriodora* and *Eucalyptus drepanophylla* woodland with an understorey dominated by *Themeda triandra*. *Lophostemon confertus* and *Xanthorrhoea* sp. were also common in the shrub layer at the site. The site was considered to belong to Regional Ecosystem 8.12.7c (EPA, 2003b). The Crediton State Forest site contained *Corymbia trachyphloia*, *Corymbia intermedia*, *Eucalyptus portuensis*, *Lophostemon suaveolens* tall open woodland with a sparse mid storey of *Allocasuarina littoralis* and an understorey dominated by *Xanthorrhoea* sp. and *Imperata* cylindrica. This site was considered to be Regional Ecosystem 8.12.7 (EPA, 2003b). A total of three specimens were vouchered and sent to the Queensland Museum (QMJ79953, QMJ79968, QMJ79955).

This new record extends the known range of the species by approximately 450km. The question arises whether this record represents an isolated population or whether the species distribution is continuous along the Great Dividing Range north of Kroombit Tops. Although the species is regarded as being common in Queensland under the *Queensland Nature Conservation (Wildlife) regulation 1994*, more fauna surveys are required to target the mesic habitats along the Range to define the exact range limits for this species.

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Literature Cited

COGGER, H.G. 2000. Reptiles and amphibians of Australia 6th ed. (Reed New Holland: Sydney).

CZECHURA, G.V. & WOMBEY J. 1982. Three new Striped Skinks (*Ctenotus*, Lacertilia, Scinidae) from Queensland. Memoirs of the Queensland Museum 20(3): 639-645.

ENVIRONMENTAL PROTECTION AGENCY 2003a. WildNet (Database). Environmental Protection Agency. Brisbane. 19 September 2003.

WESTERN AUSTRALIAN MUSEUM 2003. FaunaBase (Database). Western Australian Museum. Perth.

WILSON, S. & SWAN G. 2003. A complete guide to reptiles of Australia. (Reed New Holland: Sydney).

ENVIRONMENTAL PROTECTION AGENCY 2003b. Regional Ecosystem Description Database (REDD). Version 4.0. Updated September 2003.

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THE CHIRONOMIDAE (DIPTERA) LARVAE OF ATHERTON TABLELAND LAKES, NORTH QUEENSLAND

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The invertebrate biota of the benthos of lakes can provide an historical record of ecological (including climate) change through their preserved record in dated sediments. Such records are available through the remains of Chironomidae (Diptera) larvae recovered from lake sediments. However, to interpret the palaeo-assemblages recovered, the modern biota must be known and identifiable. Here we review, provide notes and offer an illustrated identification guide to the larval stages of Chironomidae revealed by surveys of three major Atherton Tableland lakes (Barrine, Eacham and Euramoo). Genera can be identified from variably incomplete palaeomaterial and can convey much information: here we report 8 genera belonging to the subfamily Tanypodinae, 2 to the Orthocladiinae, and 20 to Chironominae. Some are monotypic; in several genera named species can be recognised, whereas in others species-level diversity cannot be established on the basis of larval morphology. Larvae clearly identifiable as belonging to *Parakiefferiella* requires an expansion of the existing generic diagnoses in having a bifid SI seta and 3-4 short setae in a ventromental beard. Distributions outside the immediate area tend to be northern Australian to Asian, with little or no evidence of cool/mesotherm, southern-connected (temperate 'Gondwanan') taxa. ❑ *Chironomidae, larvae, north Queensland, Atherton Tableland.*

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Studies of the lakes of the Atherton Tableland in tropical North Queensland have allowed insights into the history of the area, and by extrapolation, the Australian continent. Selected biotic proxy indicators (Cohen, 2003), notably pollen, diatoms and chironomid larval head capsule subfossil remains, have been extracted from the accumulated lake benthic sediments as time-series samples to deduce past climate and assess the effects of human activities, such as fire. In contrast to pollens, chironomid larval head capsules allow near species-level determinations, and perhaps a finer control for the time of deposition with respect to the investigated time horizons.

Our studies of Chironomidae in lakes of the Atherton Tableland have concentrated on Lakes Barrine and Euramoo for palaeosediment and modern studies, and include Lake Eacham for neontological studies alone. The recent fauna is the focus of this paper, since understanding the extant fauna and its contemporary distribution on the continental-scale is fundamental to deducing past events.

Australian lacustrine Chironomidae have been investigated less intensively than those of the lotic (running waters), with no national survey. Previous Australian lacustrine studies were conducted when the taxonomic knowledge of immature stages of Australian chironomids was in its infancy. Furthermore, these studies relied upon collections of benthic larvae, often restricted to profundal sediments. Immersed wood and floating materials, attached sponges, and macrophytes were poorly sampled. We can integrate and overcome the effects of variation associated with substrate heterogeneity and diel emergence patterns through collection of pupal exuviae — the cast skin left on the water surface at adult emergence. Shoreline and nearshore accumulations of exuviae thus establish effective independence from particular larval habitats.

Previous inventories of Australian lacustrine chironomid diversity give a general impression of modest to low species-richness judged from larvae, and often greater richness based on pupae, as reviewed by Wright & Cranston (2000). In surveys of macrobenthos of Tableland lakes, Chironomidae were included only by Timms (1979) who used a Birge-Ekman grab to sample 15 stations in Lakes Barrine and Eacham and 4

stations at Lake Euramoo and reported 7 species as larvae from Lake Barrine, 8 species from Lake Eacham and none from Euramoo. Few chironomid taxa including *Procladius* Skuse, 1889 and *Chironomus nepeanensis* Skuse, 1889 were associated with the profundal and taxa such as *Cryptochironomus* Kieffer, 1918 at Lake Barrine, and *Coelopynia* Freeman, 1961 and *Cryptocladopelma* Sæther, 1971 at Lake Eacham were confined to the littoral zone. The absence of macrobenthos in the profundal of Lake Euramoo was attributed to the extremely flocculent nature of the substratum and anoxic conditions present during long periods of lake stratification (Timms, 1979). Our pilot studies of pupal exuviae at Lake Euramoo revealed a larger diversity. Subsequent collections from Eacham and intensive studies at Barrine and Euramoo to associate larvae with exuviae, and extraction of larval head capsules provided evidence of potentially over 40 shared and unique species in total. Species richness assessed by subfossil head capsules is higher than in benthic larval surveys, with taxa such as *Zavreliella marmorata* Wulp, 1859, *Thienemanniella* Kieffer, 1911, *Microchironomus* Kieffer, 1918, *Riethia* Kieffer, 1917, and *?Skusella* sp. present only amongst subfossil assemblages.

Here we provide taxonomic substantiation to accompany reconstructions based on chironomid larval remains for Lakes Barrine (Dimitriadis & Cranston, 2001) and Euramoo (Haberle et al., unpubl. data).

MATERIALS AND METHODS

The three study sites are maar crater lakes lying between 17°10' and 17'S and 145°37' and 38'E at elevations of 720-746m a.s.l. on the Atherton Tableland, close to the current western rainforest ecotone. Lakes Barrine and Eacham are deep (67m, 63m, respectively), whereas the sampled southern basin of Euramoo is shallower at 17m. Lake Barrine has the greatest surface area (1.03km^2) more than twice the area of Eacham (0.46km^2) and Euramoo (0.4km^2). All lakes are partially to completely stratified, slightly acidic, humic and dilute. The steepness of crater slopes preclude extensive littoral swamps from Lakes Eacham and Barrine, but a more extensive zone of *Phragmites*, *Blechnum* and *Cyperus* exists at Lake Euramoo. Further details on morphology, physico-chemistry and palaeolimnological studies are provided by Walker (1999), Dimitriadis & Cranston (2001) and Haberle et al. (unpubl. data).

Sampling chironomids involved a variety of collection methods. Pupae and their exuviae were collected by nets with a 300μm mesh at the water surfaces along windward shores. Larvae were collected live from the shallow littoral zones with similar sized mesh nets. Profundal larvae were sampled by Ekman grab (e.g. Veijola et al., 1996). Palaeosediments from Lake Euramoo were collected using a modified Livingstone piston corer with a core tube diameter of 5 cm whereas sediments from Lake Barrine were recovered using a Mackereth corer.

Larval materials were collected from Lake Euramoo in June 1999, and from Lake Barrine in April and June 1997, and in April, July and October of 1998. Pupal exuviae were collected from Barrine and Lake Eacham on these sampling occasions and opportunistically on other occasions.

Isolation of 3rd and 4th instar chironomid head capsules generally followed the procedures outlined by Walker (1987, 2001). Sediment samples were deflocculated with warm water running through 60 μm mesh. Residues retained on sieves were backwashed into plastic vials and sorted in a Bogorov counting tray under 25-50 × magnification with a Wild Heerbrugg dissecting microscope. Head capsules were transferred to drops of water on cover-slips using #4 forceps. Cover-slips containing approximately 15 head capsules were dried and mounted onto glass slides with Euparal for later identification. Remains were identified under 100-400 × magnification using an Olympus BH2 compound microscope.

The association between larva, pupa and adult necessary for full taxonomic descriptions has been attempted by rearing live larvae individually through to the adult. Live larvae were placed individually in a few ml of native (or tap) water in cotton-wool stoppered 50 × 10mm glass vials, and maintained at cooler than ambient temperatures, without aeration. Any emerged adults and associated exuviae were preserved in 70% ethanol.

Microscope slide preparation involved clearing where necessary with 10% KOH, neutralisation and initiation of dehydration with glacial acetic acid, then mounting from propan-2-ol (isopropanol) into Euparal. Exuviae were displayed by dissecting the cephalothorax from the abdomen, and attempts were made to remove pharate adults from exuviae.

Voucher specimens of larvae of most species are deposited in the Queensland Museum, others and pupal exuvial specimens are in the Australian National Insect Collection, Canberra, which is the primary repository for Australian Chironomidae.

Photographs were taken with an Automontage™ system, allowing automated retention of focused parts of a sequence of exposures at different focal depths. All subsequent manipulations were made in Adobe Photoshop.

TAXONOMY

Subfamily TANYPODINAE

This subfamily comprises many genera in which the larvae are predominantly, but not exclusively predatory. Previous keys to larvae, including Wiederholm (1983), have used dimensions of the head capsule, which is fraught with error associated with variable compression, and certainly does not work for fragmentary subfossil heads, nor imperfectly prepared slide mounts. Features of the ligula (the toothed part of the hypopharynx), the paraligulae, inner teeth of the mandible and the frequently reduced mentum all assist in identification (Fig. 1A). However, Kowalyk (1985) discovered very useful variation in the position and shape of cephalic setae and sensory pits on the ventral and dorso-lateral surface of the head capsules of Tanypodinae. Although the setae often are missing or highly translucent, the relative positions of pits from which they arise have widespread utility. The arrangement of the pits of the ventral setae (SSm - seta submentum, S9, S10, cephalic setae 9 and 10) and ventral pore (or 'pit') (VP) alone provides much distinguishing detail in the tribe Pentaneurini (Cranston, 1996; 2000b), although informative variation exists amongst non-pentaneurine tanypods (e.g. Figs 1D,E; Kowalyk, 1985; Rieradevall & Brooks, 2001) and also in dorsal/dorsolateral setae and the dorsal pore. In the figures that accompany this paper, the ventral head is orientated with the anterior direction towards the top to show the setae and ventral pore of right sides.

Clinotanypus Kieffer, 1913 (Fig. 1A-D) is represented in Australia by one named species, *C. crux* Wiedemann, 1824, an Indian species recognised as Australian by Freeman (1961) based on adults from northern New South Wales and Queensland. Although larvae clearly ascribable to *Clinotanypus* are widespread in warm standing waters, rearing has proved difficult. Allocation of all these northern eurythermic larvae to the species *C. crux* is not contradicted by limited pupal exuvial or adult evidence. Larvae, pupal exuviae and rearings have been made from Lake Barrine only.

Coelopynia Freeman, 1961 (Fig. 1E,F) is a monotypic genus endemic to Australia, whose immature stages were described by Roback (1982a). *Coelopynia pruinosa* Freeman, 1961 occurs in lakes and rivers from north Queensland to Tasmania, and as far west as the Kimberley and Millstream. We found *Coelopynia* larvae only in Lake Eacham, although we have subfossil material from Lake Barrine where Timms (1979) recorded the taxon.

Fittkauimyia Karunakaran, 1969 (Fig. 1G,H) was erected for a distinctive tanypod reared from a ditch in Singapore. Roback (1982b) described the immature stages from Australia. The sole eastern hemisphere species *Fittkauimyia disparipes* Karunakaran, 1969 appears to be widespread throughout south-east Asia to Australia, where it occurs as far south as the southern and subcoastal lagoons in southernmost NSW. Larvae live in rivers and pools, and in the Northern Territory the genus tolerates high acidity and metals in polluted flow from abandoned mines (Hardwick et al., 1995) and organic, industrial and sewage contaminated lagoons (S. Dimitriadis pers. obs.). Larvae, pupal exuviae and subfossil head capsules were found in Lakes Barrine and Euramoo.

Procladius Skuse, 1889 (Fig. 1I) is a common and often abundant taxon, in which, worldwide, species-delimitation is difficult in any life-history stage. Recognition of three segregates of pupal exuviae that correspond to the described species of adults in Australia, is conservative and perhaps underestimates the diversity. Pupal exuviae of *Procladius* from Eacham and Barrine all belong to *P. squamifer* Freeman, 1961 whose larva seems indistinguishable from *P. paludicola* Skuse, 1889. In much of mid- and southern Australia these two species may co-occur, although *P. squamifer* perhaps is less tolerant of polluted conditions.

Tribe PENTANEURINI

Ablabesmyia Johannsen, 1905 (Fig. 2B,D,E) is a distinctive genus of pentaneurine tanypod, sharing with *Paramerina* Fittkau, 1962 the divided basal palp segment and having one or two claws of the posterior parapod darkened (the latter feature has been stated to be diagnostic for *Ablabesmyia* but Australian *Paramerina* may have a darkened claw, and some individuals of *Ablabesmyia* may have all claws pale). Two larval taxa of *Ablabesmyia* are distinguishable: *A. hilli* Freeman, 1961 that has the palp divided into 4 sections (Fig. 2B), and *A. notabilis* Skuse, 1889

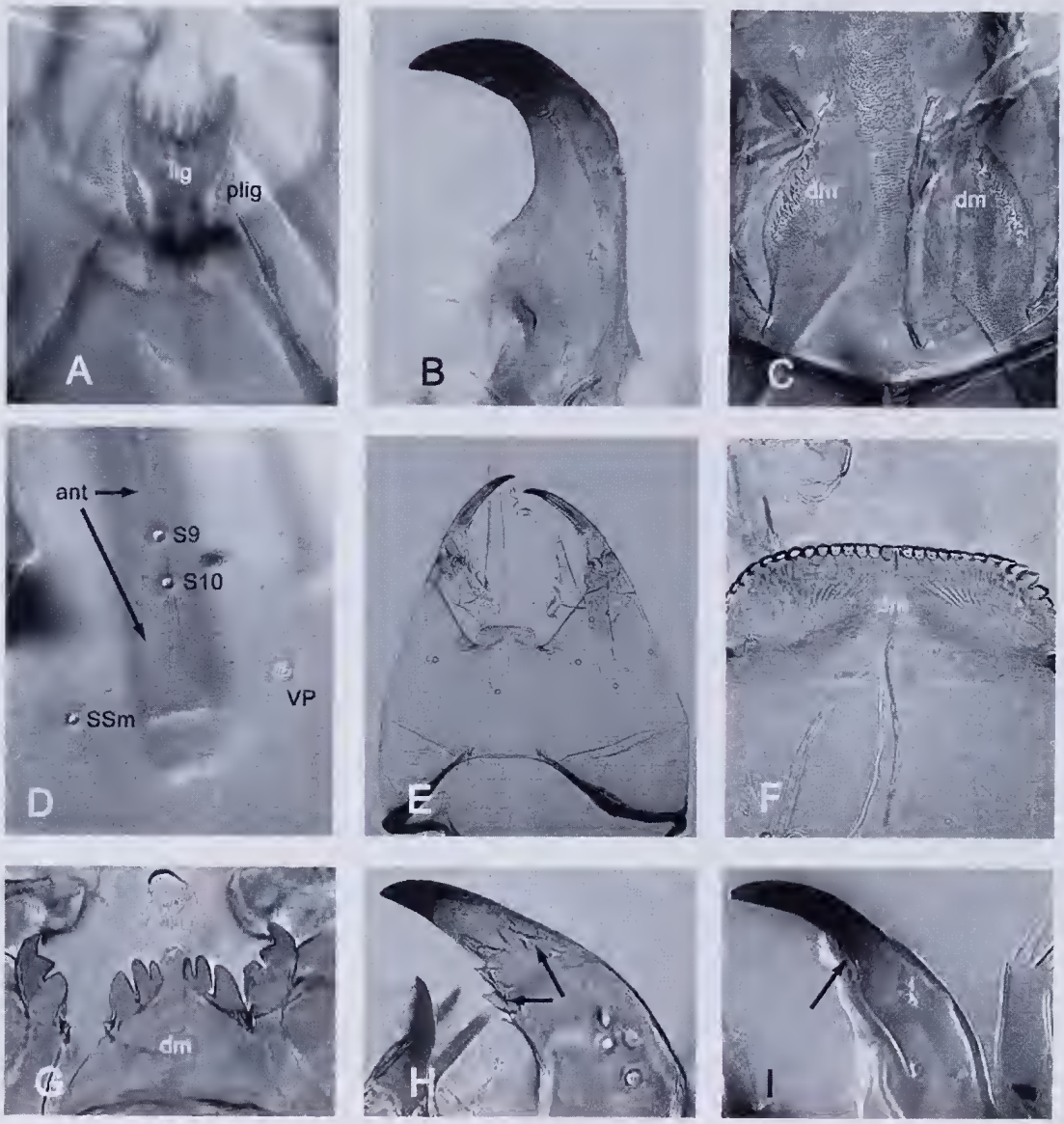

FIG. 1. A-D, *Clinotanypus crux*: A, ventral head, ligula (lig), paraligula (plig); B, mandible; C, dorsomental teeth (dm); D, antenna (ant), ventral setal pits and pore (S9, 10 - cephalic seta 9, 10, SSm - seta submentum, VP - ventral pore). E-F, *Coelopynia pruinosa*: E, ventral head. F, dorsomentum (dm). G-H, *Fittkauimyia disparipes*, G, dorsomentum (dm); H, mandible. I, *Procladius squamifer*: mandible.

with a bipartite palp. There is much variation, including in relative lengths of palp segments and intensity of pigment of the posterior parapod claws, suggesting either geographic variation or further, unrecognised, species.

Larvae identified here as belonging to *A. hilli* have only 1 dark posterior parapod claw (Fig. 2D), have 4 parts to the palp (3 of which are pigmented, the base hyaline, Fig. 2B). Only pupae have been found that may belong to *A. notabilis*, whose larva has only two parts to the palp, and 2 (or 3) dark posterior parapod claws. Separation of pupae of *A. hilli* from *A. notabilis* is difficult, relying on somewhat subjective assessment of the shape of the thoracic horn — more oval for *hilli*, more elongate in *notabilis*.

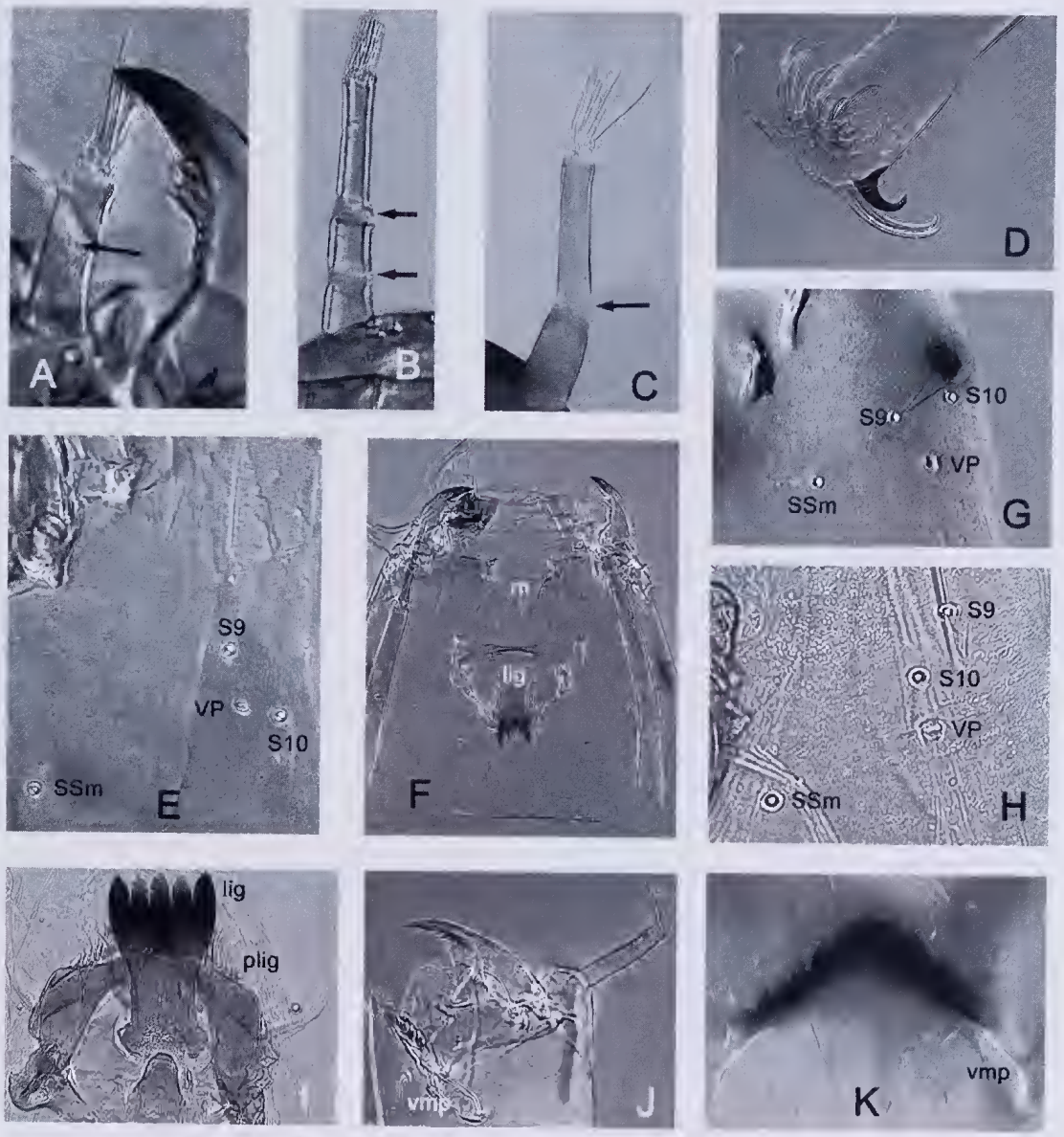

FIG. 2. A, *Monopelopia* sp.: undivided maxillary palp. B, D-E, *Ablabesmyia hilli*: B, divided (arrowed) maxillary palp. D, posterior parapod; E, ventral setal pits and pore (S9,10 - cephalic seta 9, 10, SSm - seta submentum, VP - ventral pore). C, *Paramerina* sp.: divided (arrowed) maxillary palp. F-G, *Monopelopia* sp., F, ventral head, ligula (lig), mentum (m); G, ventral setal pits and pore (S9,10 - cephalic seta 9, 10, SSm - seta submentum, VP - ventral pore). H-I, *Paramerina* sp., H, ventral setal pits and pore (S9, 10 - cephalic seta 9, 10, SSm - seta submentum, VP - ventral pore). I, ventral head, ligula (lig), paraligula (plig). J, *Nanocladius* sp, right half ventral head capsule, ventromental plate (vmp). K, *Parakiefferiella* sp., mentum and ventromental plate (vmp).

Undoubtedly *A. hilli* is the commoner species where both occur in Lakes Eacham and Barrine. Despite contemporary abundance in the two lakes, and the reported presence of the genus by Timms (1979), no subfossil material was recovered. Elsewhere both species appear to be tolerant of organic pollution and thermal stress; perhaps their recent occurrence in Atherton lakes relates to a decline in water quality.

Monopelopia Fittkau, 1962 (Fig. 2A,F,G) a pentaneurine genus, unusual amongst Australian Chironomidae in that it is recorded solely on larvae, none of which have been reared or associated with pupal or adult stages. Generally identifications of Pentancurini based upon larva alone have been uncertain, but in this case a suite of distinctive features render it certain. The inner mandibular teeth are well developed (for a pentaneurinc) (Fig. 2A), the apical 2/3 of the basal antennal segment is dark, and the ventral cephalic setae distinctively aligned (Fig. 2F,G).

Monopelopia larvae have been found in swampy shallow billabongs along the Victorian River Murray and in similar dystrophic lakes further south in the State. A larva was collected from Lake Euramoo and subfossil head capsules were abundant in the sediments.

Paramerina Fittkau, 1962 (Fig. 2C,H,I) a globally-distributed pentaneurine genus containing a swarm of species with rather little morphological differentiation in any stage. The genus is distinctive in the larva, with the basal palp segment divided into two, with the division 1/3 from the base and the ring organ in the thinner membrane between the two parts (Fig. 2C). The distribution of setal scars and pore on the ventral head is characteristic (Fig. 2H). Differentiation of species in Australia by Roback (1982a, b) was based largely on morphometries from few specimens. Size variation is now known to be great across the continental range and the basis for species segregation may be confused by unstudied allometric variation making species segregation difficult. Pupal exuviae from Lakes Barrine and Eacham appear monomorphic, with a distinctivcly small plastron plate on the thoracic horn. This resembles that shown by Roback (1982a,b) for *P. levidensis* Skuse, 1889 but reared (though pharate) adults have dark wings (perhaps due only to dense dark hairs or with some pigment on the membrane) and dark smears on the thoracic pleurae unlike the adult type of *P. levidensis*. Without complete revisionary study, probably necessitating molecular data, we cannot assign the taxon to a described species. A smaller taxon, *Paramerina parva* Freeman, 1961 with a larger pupal plastron plate, is named from northern Australia. Despite *Paramerina* being quite common in contemporary Lakes Barrine and Eacham, no subfossil heads have been found, though common as subfossils at Lake Euramoo. Some *Paramerina* species are pollution-tolerant and their recent presence may indicate some deterioration in water quality in Eacham and Barrine.

Subfamily ORTHOCLADIINAE

Orthocladiinae is speciose in Australia, as elsewhere, in a diversity of larval habits especially lotic ones. Cold, oxygenated lakes have much higher orthoclad diversity than warm, oxygen-depleted ones. That only two taxa are present in modern Atherton lakes is surprising, as is the lack of species of the eurytopie genus *Cricotopus* Wulp, 1874. This latter absence seems genuine — no exuviae or subfossil head capsules of this genus were found in any site studied. We can provide no explanation for this, because one to several species of these algal grazers are expected in any tropical billabong thus far studied. The only orthoclad taxon additional to those mentioned below is *Thienemanniella* Kieffer, 1911 found as a 2000-1000 yr subfossil from Lake Barrine. Generic concepts agree with those in Wiederholm (1983) and Cranston (1996, 2000b) except for some details in *Parakiefferiella* Thienemann, 1936 (q.v.).

Nanocladius Kieffer, 1913 (Fig. 2J) is a world-wide distributed genus, modestly speciose in the Holarctic, with a less well known, perhaps less diverse, southern continental distribution. In Australia two speeies are known from Western Australia, while in the east what appears to be a single species is widespread in running and standing waters. Few rearings exist to test the species concept, but apparently the same unnamed species is figured by Cranston (1996) as *Nanocladius* sp. The pupa keys to the bicolor group in the Holarctic guide (Coffman et al., 1986).

Parakiefferiella Thienemann, 1936 (Fig. 2K) is a worldwide genus which presents a wealth of morphological features of larvae and pupae that can allow species segregation. Nevertheless, although four pupal exuvial types have been recognised in Australia (Cranston, 1996) no species are described formally yet. The generic diagnosis for larval *Parakiefferiella* in Wiederholm (1983) has to be emended to incorporate some unusual features exhibited by this undescribed Australian taxon: there is a ventromental beard of 3-4 short but distinct setae, and the S1 seta on the labrum is bifid.

Subfamily CHIRONOMINAE

Species of this subfamily always are dominant in warm standing waters. The apparently universal presence of haemoglobin in the larva allows uptake of oxygen from warm, oxygen-depleted benthic waters. As expected, the diversity of this

subfamily is high in the lakes of the Atherton Tableland, with 20 genera reported. *Zavreliella* Kieffer, 1920, *Microchironomus* and *Riethia*, recorded as subfossils were not found in modern collections. Two diverse genera, *Polypedilum* Kieffer and *Tanytarsus* v.d. Wulp, are problematic to identify as larvae and the treatment here remains incomplete. Generic concepts agree with those in Wiederholm (1983) and Cranston (1996, 2000b).

Tribe CHIRONOMINI

Chironomus Meigen, 1803 (Fig. 3A,B) is a worldwide genus with many species described predominantly on adult male genitalia and on distinctive cytology. Isolated larval head capsules cannot be identified reliably to species, and the variation in pupal exuviae has yet to be associated with named species. *Chironomus* larvae and pupal exuviae have been recovered from most tableland lakes on most sampling occasions, but numbers have never been high. Timms (1979) reported *Chironomus nepeanensis* Skuse, 1889 from both Eacham and Barrine, identified by Jon Martin and therefore reliable. To our eye, only one morphotype was present, probably attributable to *C. nepeanensis*.

Cladopelma Kieffer, 1921(Fig. 3C) is a globally-distributed genus. In Australia, only *C. curtivalva* Kieffer, 1917 has been recognised. Although there is much morphological variation in the pupa, especially in the shape of the spur ('comb') on the posterolateral of segment VIII, as yet no discrete units that may be species can be segregated. *Cladopelma* has been found as a modern exuviae from Lake Eacham, and as a subfossil larva from Barrine.

Conochironomus Freeman, 1955 (Fig. 3D) is distributed in Africa, southeast Asia and Australia. Larvae have a six-segmented antenna with Lauterborn organs alternate on the apices of segments 2 and 3, and a uni-coloured brown mentum with four subequal median ventromental teeth delimited (Fig.3D). The genus was revised for Australia (Cranston & Hare, 1995) in all life history stages. Larval *Conochironomus* have been reported from L. Barrine (Timms, 1979) from which lake we have identified larvae of *Conochironomus cygnus* Cranston & Hare, 1995 from 6m depth. The genus exists also as subfossils in L. Barrine, and as exuviae from L. Eacham. *C. cygnus* is reported previously from Blue Lake on North Stradbroke Island, numerous streams and billabongs in the Kakadu area (Northern Territory), and the Fitzroy River in the Kimberley of Western Australia. Since Cranston & Hare (1995), more southerly distributions to southernmost subcoastal NSW have been revealed, in shallow, summer-warm waters.

Cryptochironomus Kieffer, 1918 (Fig. 3E) is a globally-distributed genus. In Australia, only *C. griseidorsum* Kieffer, 1917 has been recognised from nearly throughout the continent. Although there is much morphological variation in all life history stages, as yet no coherent units that may be discrete species have been segregated. Thus we treat all *Cryptochironomus* as belonging to the one described species. Larval *Cryptochironomus* have been reported from Lake Barrine (Timms, 1979) and we have identified pupal exuviae from Lake Eacham and from Barrine as contemporary and subfossil larvae.

Dicrotendipes Kieffer, 1913 (Fig. 3F,G,H) is a globally-distributed genus, with a quite speciose radiation in Australia. As a larva the genus is distinctive by the squat ventromental plates, and frequent presence of a 'fenestra' on the anterior frontoclypeus on the dorsal head. Provisional keys to larvae and pupae in Cranston (1996) allows identification of two species in the Atherton lakes. Larval *Dicrotendipes* have been reported previously from Lake Barrine (Timms, 1979) and we have identified larvae and pupae of *Dicrotendipes flexus* Johannsen, 1932 from Lakes Eacham and Barrine as contemporary and subfossil larvae. In Euramoo, *Dicrotendipes jobetus* Epler, 1988 is abundant as contemporary larvae and as subfossil head capsules. *D. jobetus* is an essentially northern and central Australian species, found predominantly in warm standing waters. *D. flexus* is similarly northern and lentic, but with a narrower distribution that does not include central Australian waters. *D. flexus* is known outside Australia from much of south-east Asia, where it is tolerant of some eutrophication.

The two species can be separated as larvae based on the mandible of *D. jobetus* having strong crenulations on the outer margin (Fig. 3H) and the possession of a strong fenestra (oval cuticular thinning) (Fig. 3G). *D. flexus* has a very faint fenestra and smooth outer mandible. These features will not separate all possible regional *Dicrotendipes* species for which Cranston (2000b) should be consulted.

Evidently *Dicrotendipes* is diverse regionally, since nearby artificial Emerald Dam has *D. balciunasi* Epler, 1988 and *D.* sp. 'K3' as well as *D. jobetus*. The identity of the species of larval

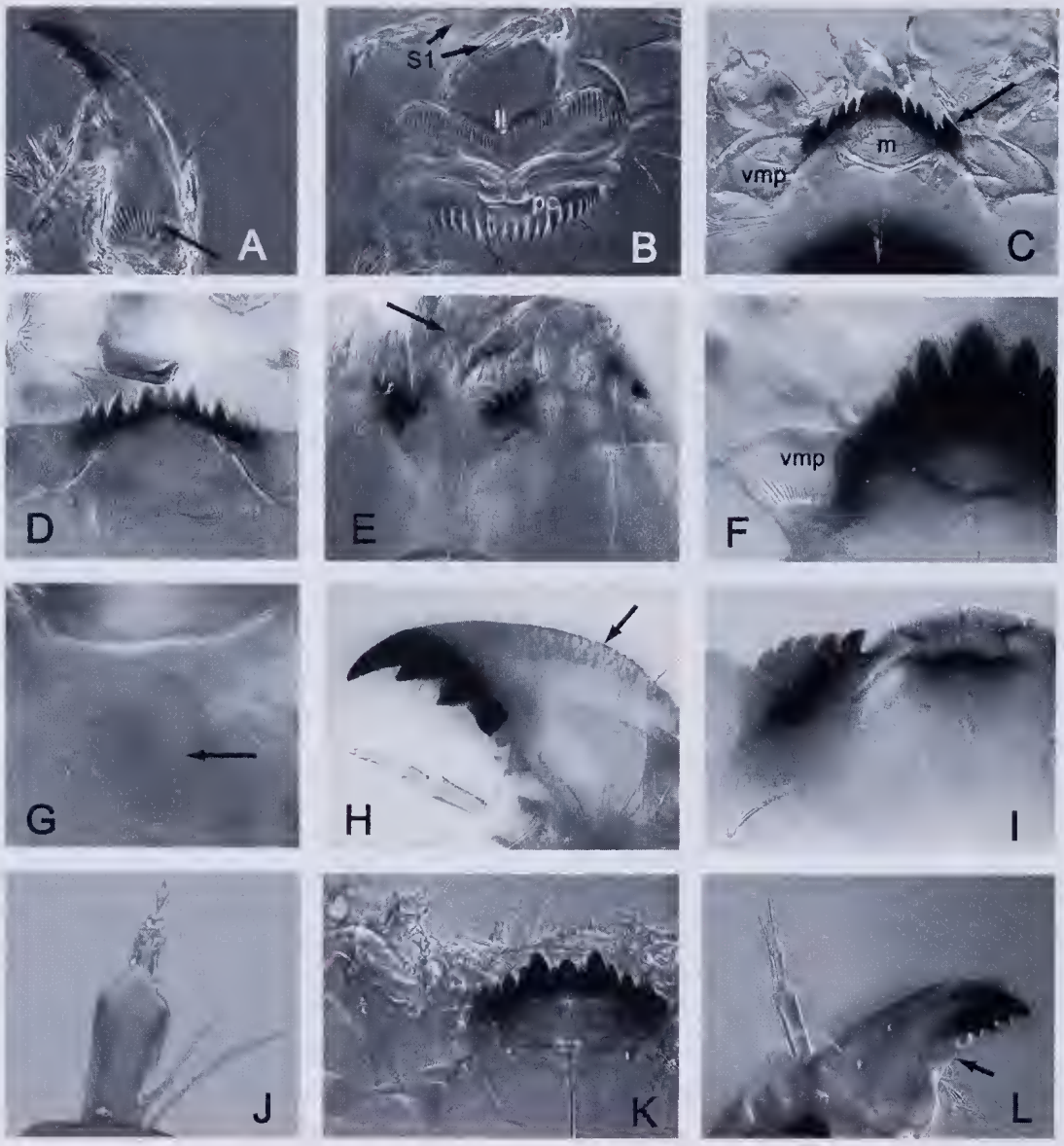

FIG. 3. A-B, *Chironomus* sp., A, mandible with basal furrows (arrowed). B, labral lamellae (ll), pecten epipharyngis (pe) and setae. C, *Cladopelma curtivalva*, mentum (m), ventromental plates (vpl). D, *Conochironomus cygnus*, mentum, ventromental plates. E, *Cryptochironomus griseidorsum*, mentum, ventromental plates. F-H, *Dicrotendipes jobetus*, F, half mentum and ventromental plate (vmp); G, dorsal fenestra (arrowed); H, mandible. I, *Harnischia* sp., half mentum and ventromental plate. J, *Harrisius* sp., antennal segments. K-L, *Kiefferulus* 'tinctus', K, mentum, ventromental plate; L, mandible, antenna.

Dicrotendipes recorded from Lake Eacham by Timms (1979) is unknown.

Harnischia Kieffer, 1921 (Fig. 3I) is represented in Australia by *H. curtilamellata* Malloch, 1915 a species described from North America, based on its proposed senior synonymy with *Cryptochironomus dycei* Freeman, 1961. Without detailed comparative study and revision of the genus on a global scale, this identification is accepted. The taxon is reported from the

Atherton lakes from exuviae only, from Lakes Barrine and Eacham. The genus is widespread in Australia especially in sandy-bedded rivers.

Harrisius Freeman, 1959 (Fig. 3J) larvae mine in wood or leaf packs and occur principally in running waters but sporadically in lakes. Pupal exuviae were found in Lake Eacham, but larvae have not yet been found in any Atherton lake. Larvae closely resemble those of another wood-mining genus, *Stenochironomus*. Principal distinction appears to be in antennal segment lengths, in which antennal segment 3 of *Harrisius* is half the length of the 4th (Fig. 3J), whereas in Australian *Stenochironomus* the 3rd appears subequal to the 4th (not illustrated through lack of specimens for photography). Distribution is sporadic along the east coast of Australia.

Kiefferulus Goetghebuer, 1922 (Figs 3K,L; 4A,B) is a diverse, worldwide genus. Larval *Kiefferulus* can be recognised by the multi-toothed premandible (Fig. 4B) and characteristic mentum (Figs 3K, 4B). Four larval morpho-types are known from Australia, one certainly comprising 3 cryptic species, *Kiefferulus cornishi* Martin 1996, *Kiefferulus intertinctus* (Skuse, 1889) and *Kiefferulus paratinctus* Martin, 1964 (a composite referred to here as *K.* 'tinctus'). Compared with previous works on Australian *Kiefferulus* (Cranston et. al., 1990; Cranston, 1996), here *Kiefferulus calligaster* (Kieffer, 1911) replaces *Kiefferulus tumidus* Johannsen, 1932 and *Kiefferulus barbitarsis* (Kieffer, 1911) replaces *Kiefferulus tainanus* Kieffer, 1912, both being senior subjective synonyms. Amongst other recorded taxa *Kiefferulus longilobus* Kieffer, 1916 is restricted to saline subcoastal habitats and *K. barbitarsis* has not been recorded from Atherton lakes. Distinctive *Kiefferulus martini* Freeman, 1961 resembles a species of *Xenochironomus* Kieffer, 1921 (Fig. 5C) in having a brush of long labral setae, and may be expected in certain Tableland lakes.

Two species of *Kiefferulus* co-occur in modern Lake Euramoo: *K.* 'tinctus' and *K. calligaster*, but only larvae of the former were found as subfossils. *K. calligaster* is distinguished on the mandible, which has a molar bulge (arrowed, Fig. 4A) rather than the straight mola of 'tinctus' (arrowed, Fig. 3L). The bulging outer mentum of *calligaster* (Fig, 4B) compares to the almost straight margin in 'tinctus' (Fig. 3K).

K. 'tinctus' is widespread in Australia from Kakadu to Tasmania, whereas *K. calligaster* is a northern species, extending from tropical Australia to India and south Japan.

Microtendipes Kieffer, 1915 (Fig. 4C,D) is recorded from Australia based on the reported presence of the African species *M. umbrosus* Freeman, 1955. With the present state of knowledge of the genus, this determination is accepted. *M. umbrosus* larvae, subfossils and rearings have been made from Lake Barrine, exuviae collected from L. Eacham and subfossils recovered from sediments of Lake Euramoo. Distribution in Australia seems restricted to Queensland, where previous records include abundance in experimentally-polluted channels west of Brisbane (P.S. Cranston, pers. obs.).

Parachironomus Lenz, 1921 (Fig. 4E,F) is a world-wide genus represented in Australia by several predominantly undescribed species, based on few rearings but a diversity of exuvial types. Two exuvial morphotypes are known from the region, 'K1' and 'K2', each recognised previously from surveys in Kakadu, and both found in Lake Barrine. One larval type associated tentatively with 'K2' was found as a subfossil in Lake Euramoo.

Polypedilum Kieffer, 1912 (Fig. 4G-J) is a diverse genus worldwide, and Australia is no exception. Species are differentiated primarily on male genitalia, with pupal exuviae sometimes providing confirmatory support. Larvae are less well differentiated, and features such as mentum shape, ventromental plate structure and mandibular tooth number and shape tend to be variations on a theme, with seemingly much convergence. The relative lengths of the apical 3 antennal segments provide additional discriminatory features but antennae rarely are available on subfossils. For the tableland lakes, definite identifications have been made for 7 species, of which 3 are illustrated here (Fig. 4G-J).

Although a subgeneric structure is available in *Polypedilum* it is not possible to place the immature stages unambiguously. Users are directed to an updatable web-based key (Cranston, 2000b) for guidance in identification. In Australian keys to immature *Polypedilum* (Cranston, 1996, modified in Cranston, 2000b) the taxa are keyed without reference to subgenera, although the framework is used here to discuss the species.

In the nominate subgenus, *Polypedilum seorsum* Skuse, 1889, *Polypedilum vespertinum* Skuse, 1889 and *Polypedilum watsoni* Freeman, 1961 were found as pupal exuviae in at least one

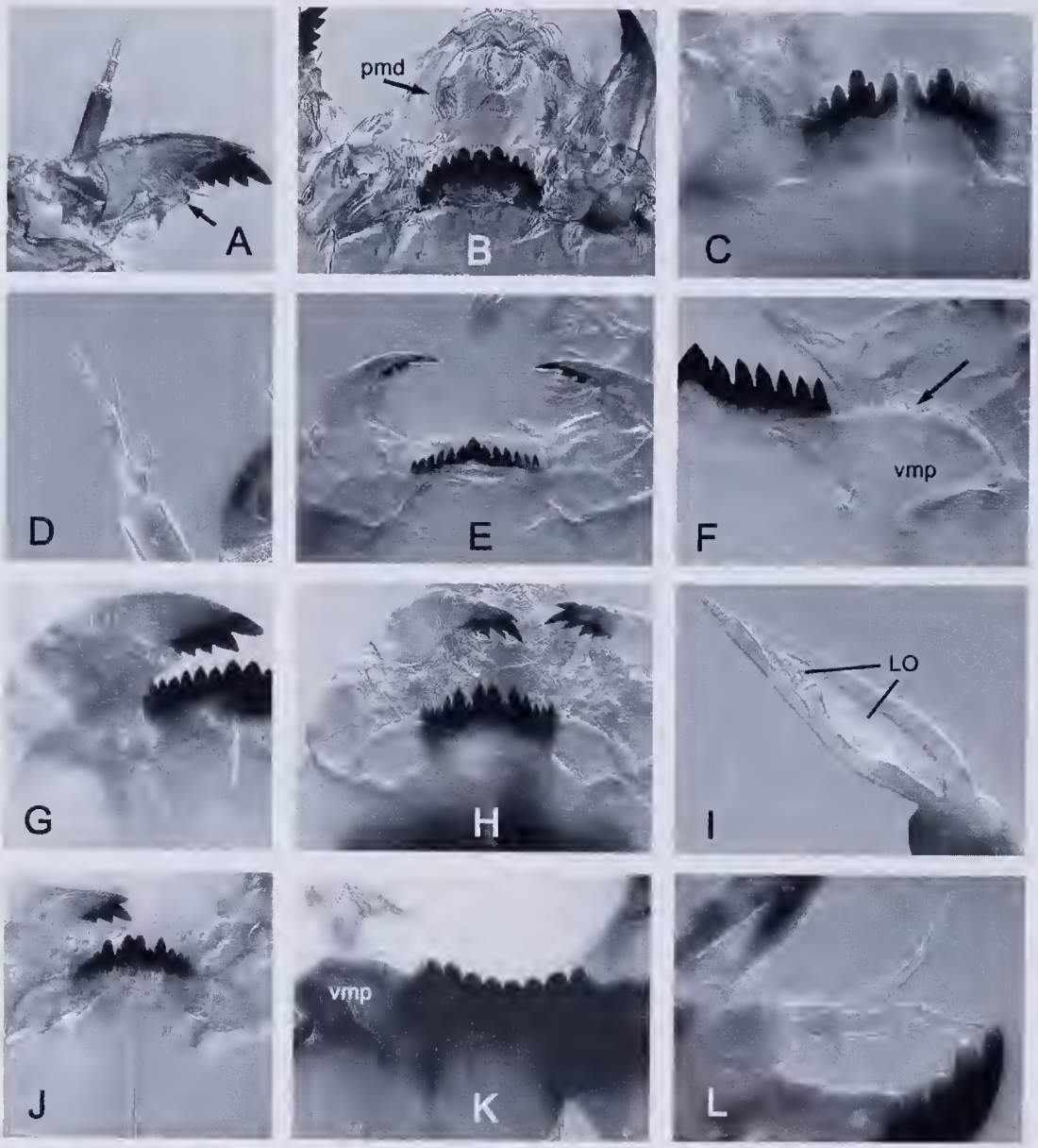

FIG. 4. A-B, *Kiefferulus calligaster*, A, mandible, antenna; B, mentum, ventromental plates, premandible (pmd). C-D, *Microtendipes umbrosus*, C, mentum, ventromental plates; D, antenna. E-F, *Parachironomus* sp., E, ventral head; F, mentum, ventromental plates (vmp), crenulated anterior margin arrowed. G, *Polypedilum leei*, half mentum, ventromental plate. H-I, *Polypedilum nubifer*, H, mentum, ventromental plate; I, antenna, Lauterborn organs (LO). J, *Polypedilun seorsum*, mentum, ventromental plate. K, *Stenochironomus watsoni*, mentum, ventromental plates (vmp). L, *Stictochironomus fluviatilis*, mandible and antenna.

regional lake, with *P. watsoni* recognised as a larval subfossil from Barrine and *P. seorsum* from Euramoo.

Three species of the likely paraphyletic or even polyphyletic subgenus *Pentapedilum* Kieffer, 1913 (Sæther & Sundal, 1999) occur in the tableland lakes: *Polypedilum (Pentapedilum) leei*

Freeman, 1961, *Polypedilum (Pentapedilum) convexum* Johannsen, 1932 and *Polypedilum (Pentapedilum)* 'K1' (Cranston, 1996). All three were present in Lakes Barrine, Eacham and Euramoo, and as larval subfossils in Euramoo and Barrine.

Polypedilum nubifer Skuse, 1889, the atypical but genotype species, was found only as a pupal exuviae in Lake Eacham. The species is typical of highly eutrophic and disturbed habitats, and may be a very recent colonist with no prior existence.

Subfossil larval head capsules that appear on the isolated menta to be close to *Polypedilum* species 'S1' and *P. prasiogaster* have been found in Euramoo and Eacham respectively, apparently without modern representation as assessed by pupal exuviae.

Stenochironomus Kieffer, 1919 (Fig. 4K) is a worldwide genus, particularly associated as larvae with immersed wood and leaves, either as a miner or grazer. *Stenochironomus watsoni* is a common, even ubiquitous species, with a characteristic larva that mines in wood. *S. watsoni* was found as a pupal exuviae and subfossil at Lake Barrine, as exuviae only at Eacham, and apparently absent from Lake Euramoo at any time. Although some immersed wood was examined, no larvae were found, as with the other wood-miner, *Harrisius* sp.

Stictochironomus Kieffer, 1919 (Figs 4L, 5A) is a worldwide genus, represented with certainty in Australia by *S. fluviatilis* (Skuse, 1889). A second species, *Stictochironomus illawara* Freeman, 1961, does not conform well to the larval generic diagnosis. *S. fluviatilis* is reported from sediments in rivers, from Arnhem Land to southern NSW, with rather few exuvial records from lakes. We have a single larva from Lake Barrine, without exuviae or subfossil material.

Xenochironomus Kieffer, 1921 (Fig. 5B,C) species are miners in aquatic sponges as larvae. This results in highly worn mouthparts, and difficulty in associating larvae with the several recognised pupal forms. Three pupal types illustrated in Cranston (1996) have been found in the Atherton lakes: *Xenochironomus* 'S1', *X.* 'K3' from Eacham and *X.* 'K4' from Barrine. Two excellently preserved larvae, without the usual sponge-spicule induced wear and with fluid gut-contents, were associated with rotting reeds in Lake Euramoo. Since none were found associated with encrusting sponges at this site, it is possible that Australian *Xenochironomus* include non-sponge-miners.

Unknown genus 'K2' (Fig. 5D,E), a distinctive pupa belonging to an undescribed taxon and recorded under the code 'unknown genus K2' in Cranston (1996) was found as exuviae in Lakes Barrine and Eacham. The larva recently associated with the 'K2' pupa was recognised as '*?Stictochironomus*'. Earlier records of exuviae were from the Kakadu/Arnhemland area of Northern Territory, predominantly from larger rivers but including some seasonally-flowing billabongs. More recent material comes from Western Australia: the Hamersleys (Fortescue Falls), north-central (Millstream, a large pool) and the south-west (a forested creek in jarrah country). Elsewhere in Queensland the taxon has been found in Cooloola National Park at Harry's Landing, and Lawn Hill National Park at Louie Creek. A southern outlier is represented by an associated larva and pupa from the Nepean River south of Sydney in NSW. A second species is represented by exuviae from the Brindabella Hills west of Canberra.

Tribe TANYTARSINI

Cladotanytarsus Kieffer, 1921 (Fig. 5F) is a worldwide genus, which is moderately species-rich in Australia, with larvae found in all types of water bodies including depositionary and brackish waters. Variation in pupal exuvial morphology suggests the existence of more species than are described, but full life history rearings necessary for associations remain too few. Only one pupal exuviae, resembling *C. bilinearis* Glover, 1973 was found at Lake Eacham; subfossils tentatively identified as this taxon were recovered from Lake Barrine.

Paratanytarsus Thienemann & Bause, 1913 (Fig. 5G,H) is a world-wide genus, and is widespread and moderately species-rich in Australia, with exuviae found in all types of water bodies. Larvae are encountered less frequently, and may inhabit typically under-sampled microhabitats. In Atherton lake surveys, only one species, *Paratanytarsus kathleenae* Glover, 1973 has been found, and only as pupal exuviae. The genus closely resembles *Tanytarsus* Wulp, 1874 and can be recognised by the pecten epipharyngis of the epipharynx comprising 3-5 finger-like lobes. Short Lauterborn organs situated on short or sessile pedestals separate nearly all species from those of *Tanytarsus* excepting an undescribed North American species (T. Ekrem, pers.

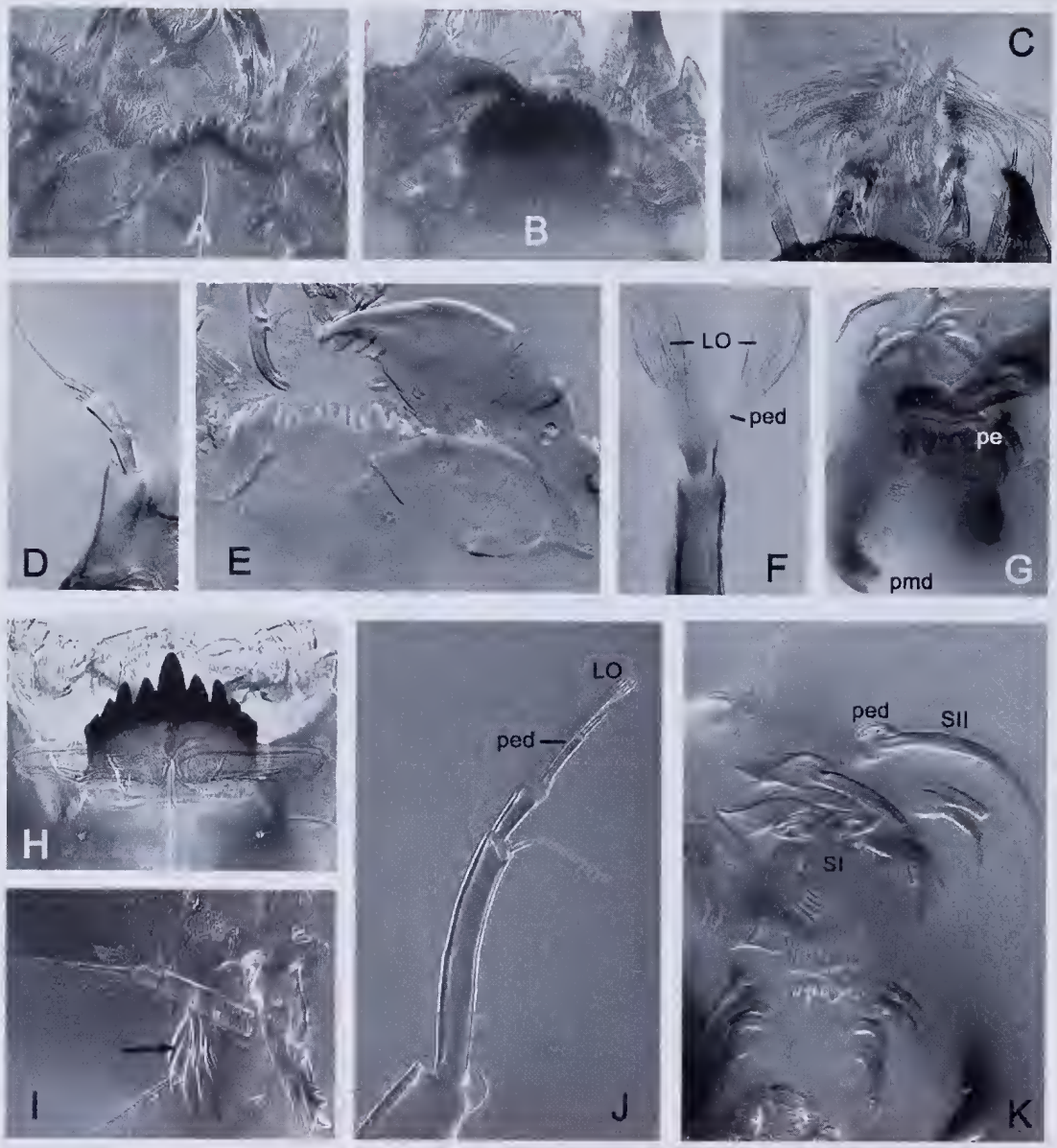

FIG. 5. A, *Stictochironomus fluviatilis*, mentum, ventromental plates, pectien epipharyngis. B-C, *Xenochironomus* sp., B, mentum; C, labrum. D-E, Unknown genus 'K2', D, antenna; E, mentum. F, *Cladotanytarsus* sp., antenna: Lauterborn organ (LO), pedestal (ped). G, *Paratanytarsus kathleenae*, labrum: pecten epipharyngis (pe), premandible (pmd). H, *Paratanytarsus* unknown species 'Euramoo', mentum and ventromental plates. I, *Stempellina australiensis*, palmate lobe at base of antenna. J-K, *Tanytarsus wendyleei*, J, antenna: Lauterborn organ (LO), pedestal (ped); K, labrum and palatum.

comm.). In subfossil material in which these features usually are missing, larval separation from *Tanytarsus* on mentum and ventromental plate structure is probably unreliable. Outside Lakes Eacham and Barrine, *P. kathleenae* is known from streams in south Queensland, and lakes, streams and rivers as far south as the subalpine area of Tasmania.

From Lake Euramoo a single larval *Paratanytarsus* recovered from decomposing reeds is distinctive

from other known congeneric larvae by the elongate median mental tooth (Fig. 5H). The only other *Paratanytarsus* from the Atherton area is a single pupal exuviae that can be allocated to no previously recognised pupal taxon (Cranston, 1996). Tergite III has posterior paired 'curtains' of posteriorly-directed fine spines, longer and denser and more transversely aligned compared to *P. kathleenae*; tergites IV and V have paired anterior spine patches resembling those of *Rheotanytarsus*. There is no spur or comb on the posterolateral corner of segment VIII.

Rheotanytarsus Thienemann & Bause, 1913 is represented in samples from Atherton only by 1 exuviae from Lake Eacham, identified using Cranston (1997) as *R. trivittatus* Johannsen, 1932. The species is known only from lotic situations from Thailand southwards to northern Victoria. No larvae have been found in lake benthos and the sole lacustrine exuviae is likely to have been a contaminant from lotic inflow, and thus no illustration is provided.

Stempellina Thienemann & Bause, 1913 (Fig. 5I) is represented in Australia by two described species: S. *australiensis* Freeman, 1961 and *S. johni* Glover, 1973. Pupal exuvial evidence and few rearings to the adult male with apparently diagnostic hypopygia suggest that this may under-represent the Australian diversity of this worldwide genus. Nevertheless, all pupal exuviae from Atherton appear to represent one species, *S. australiensis*. This taxon, figured in Cranston (1996) as *S. ?australiensis*, in the exuviae has a tapering tubular thoracic horn with few spines, a densely rugose anterior half of the thorax including two swollen tuberculose protuberances on the antero-lateral thorax. Tergal spinulation includes a medio-posterior patch of fine spinules on II just anterior to the hook row, large spinules laterally-directed only on V, and few aligned spinules on VI.

The genus is restricted to Eacham amongst surveyed lakes, but otherwise is widespread in many types of waterbodies in Australia. Larvae were not found in the neontological survey, but can be recognised easily by the palmate process on the antennal pedicel (Fig. 5I).

Tanytarsus v.d. Wulp, 1874 (Fig. 5J,K) is rich in species that are separated readily on pupal exuvial and male hypopygial features. Larvae are rather homogeneous and often are difficult to separate. Tabulated variation in antennal features, cephalic seta S3, pigment of head, mentum and anal setae and pectination of posterior parapod claws (Cranston, 2000a) allows separation of 'monsoonal tropical' Australian species of the genus, but the utility of permutations of these features on a continental scale is untested. Furthermore, identifications of subfossil material, usually rely only on the mentum and ventromental plates, and these structures show rather minimal informative variation compared to features such as the antenna that are rarely preserved.

Tanytarsus wendyleei Cranston, 2000. Described as pupa and adult only from Northern Territory, originally as *Tanytarsus* sp. 'K4' (e.g. Cranston, 1996). Recorded from Lake Euramoo here on the basis of a common larva, one of which contains a pharate pupa identical in all observable features to *T. wendyleei*, namely with paired spinule patches on the antero-median of tergites II-VI with minimal other armament on the tergites, with 1 taeniate seta posterolaterally on VI, 2 anterior and one posterior on VII and 5LS on VIII, with a dense cluster of moderate-sized teeth on the 'comb' (posterolateral corner of VIII) (see Cranston, 2000a).

The associated larva (Fig. 5J,K), which was not known to Cranston (1996, 2000a), has a yellow head capsule without darkened occipital margin; mentum yellow brown, with darkened band across mentum at bases of teeth; cephalic seta S3 stout and simple, antennal pedestal without spur; antenna shorter than head, with segments golden, fully sclerotised excepting 2nd with only apical 20% unpigmented, with stout Lauterborn organ pedestals extending beyond antennal apex by 2/3 length of 3 terminal antennal segments, with Lauterborn organs, short and scarcely broader than pedestal. The posterior parapod claws are all simple, and the procercus is squat and gold/brown, with golden apical setae.

Tanytarsus gulungul Cranston, 2000. Described from Northern Territory, Queensland and northwestern Western Australia, originally as *Tanytarsus* sp. 'K1' (e.g. Cranston, 1996). Recorded from pupal exuviae from Lake Eacham. The larva has not been recognised from Atherton lakes, but according to Cranston (2000a) may be recognisable by: antenna only slightly shorter than head, segment 2 pigmented only in sub-basal ring, apical segments 3-5 very pale, with Lauterborn organ stems extending well beyond antennal apex, and bearing short Lauterborn organs; with cephalic S3 seta long and simple; posterior parapod claws semipectinate.

T. gulungul seems to be associated with streams and large rivers; however, although this record from Eacham is the first from a lake, several tropical 'river' sites are almost lentic after the monsoonal flow diminishes.

Tanytarsus formosanus Kieffer, 1912. Reported previously in Australia as *Tanytarsus dycei* Glover, 1973, recognised recently by Ekrem (2001) as a junior synonym of the very widespread Old World *T. formosanus*. Recorded from a pupal exuviae from Lake Eacham; abundant in Emerald Creek Dam (17°03'S 145°30'E). The larva has not been recognised from Atherton lakes, but according to Ekrem (2001) may be recognised by the antenna being short (0.6 × head length), with all segments pigmented, with short stout Lauterborn organ stems not extending to apex of antenna, bearing short Lauterborn organs; S3 simple; posterior parapod claws simple.

In Australia, *T. formosanus* is essentially tropical to subtropical, from Northern Territory, and south to Brisbane in Queensland. Apparently tolerant of nutrient enrichment and experimental pesticide addition to slowly flowing water in experimental channels.

KEY TO SUBFAMILIES OF LARVAL CHIRONOMIDAE FROM TABLELAND LAKES

1. Antenna retractile into head (Figs 1D, arrowed, 1E, 2F). Hypopharynx with distinctive toothed ligula (Figs 1A, 2I), mentum often weakly sclerotised (Figs 1A, 2F) . . . . . Tanypodinae

   Antenna non-retractile (Figs 2J, 5D). Mentum a strongly sclerotised plate (the main mouthpart) (Figs 2K, 3C, 4C), with hypopharynx lacking strong ligula 2

2. Mentum associated with variably developed, but always broad and usually striated ventromental plates (Fig. 4C) . . . . . Chironominae

   Mentum without, or at most with relatively small, non-striate ventromental plates (Fig. 2J,K) . Orthocladiinae

SUBFAMILY TANYPODINAE

1. Body segments bearing longitudinal lateral dense setal fringe. Dorsomentum distinct, toothed (Fig. 1E-G) . . 2

   Body segments lacking setal fringe. Dorsomentum indistinct, not toothed (Fig. 2F) . . . . . tribe Pentaneurini 5

2. Dorsomental teeth not aligned on plate (Fig. 1C). Mandible strongly hooked (Fig. 1B) . . . . . *Clinotanypus*

   Dorsomental teeth at margin of plate (Fig. 1E,F). Mandible straight to curved, never hooked (Fig. 1E,H,I). 3

3. Dorsomentum a complete arc of subequal-sized teeth amongst which median appendage is not demarcated (Fig. 1E,F) . . . . . *Coelopynia*

   Dorsomental teeth medially interrupted by variably broad median pale median appendage (Fig. 1G) 4

4. Mandible with multiple spine-like teeth on mesal surface, without distinct basal tooth (Fig. 1H, arrowed) . . . . . *Fittkauimyia*

   Mandible without subapical spine-like teeth (Fig. 1I, arrowed) . . . . . *Procladius*

5. Base of maxillary palp undivided (Fig. 2A) . *Monopelopia*

   Basal segment of maxillary palp divided into two or more sections (Fig. 2B,C, arrowed) 6

6. One or more claws of posterior leg darker than remainder (Fig. 2D). Basal palp segment divided into 2-5 sections (Fig. 2B, arrowed); if only 2 sections, then membranous part anterior to basal 1/3. Submentum with SSm nearly aligned with VP and S_{10}, with S_9 anteromedial to alignment (Fig. 2E). . . . . *Ablabesmyia*

   All hind proleg claws yellow. Membranous division of maxillary palp about 1/3 from base (Fig. 2C, arrowed). Submentum with seta S_9 linearly aligned with S_{Sm} and S_{10}, with VP lying more posterolateral (Fig. 2H) . . . . . *Paramerina*

SUBFAMILY ORTHOCLADIINAE

1. Ventromental plates extending just lateral of outermost mental tooth; mentum black (Fig. 2K) . *Parakiefferiella*

   Ventromental plates extending more strongly lateral and posterior to base of outermost mental tooth; mentum paler (Fig. 2J) . . . . . *Nanocladius*

SUBFAMILY CHIRONOMINAE

1. Bases of SI setae fused and SII on long pedestal (Fig. 5K). Antenna always with 5 segments with Lauterborn organs distinct, sometimes on pedestals (Fig. 5J). Tanytarsini 2

   Bases of SI separate (Fig. 3B), SII rarely on pedestal. Antenna may be six segmented and Lauterborn organs alternate (Fig. 4I, arrowed, 4L), though usually opposite, sometimes indistinct (Fig. 3J,L). 5

2. Palmate lobe at base of antenna (Fig. 5I, arrowed); Head capsule very granular . . . . . *Stempellina*

   No palmate lobe at base of antenna. Head capsule smooth, non-granular 3

3. Premandible bifid (Fig. 5G). . . . . *Paratanytarsus*

   Premandible with more than two teeth (Fig. 5K) 4

4. Second antennal segment cylindrical, longer than third; small Lauterborn organs arise from long pedicels (Fig. 5J) . . . . . *Tanytarsus*

   Second antennal segment distinctly wedge-shaped, subequal in length to third segment; large Lauterborn organs arise from short pedicels (Fig. 5F). . . *Cladotanytarsus*

5. Apex of labrum with distinct brush of setae (Fig. 5C) . . . . . *Xenochironomus*

   Apex of labrum without such an anterior brush. 6

6. Head dorso-ventrally flattened. Ventromental plates without striae, with few hooks (Fig. 4K). 7

   Head not flattened. Ventromental plates distinct, striate (Fig. 3C-F) 8

7. Antennal 3rd segment short, same length as 5th, c 50% length of 4th (Fig. 3J). . . . . *Harrisius*

   Antennal 3rd segment only slightly shorter than 4th . . . . . *Stenochironomus*

8. SI seta plumose; SII not blade-like; labral lamellae present (Fig. 3B). Pecten epipharyngis usually a wide plate, rarely reduced to three sometimes serrate lobes (Fig. 3B). 9

SI and SII setae simple, frequently blade-like; labral lamellae absent (Fig. 3E). Pecten epipharyngis usually reduced to single scale, rarely toothed . . . . . Harnischia complex 16

9. Antenna five-segmented with Lauterborn organs opposite on 2nd segment or absent (Fig. 3H,L), or four-segmented with Lauterborn organs displaced along 2nd (Fig. 4I) 10

Antenna six-segmented with Lauterborn organs alternate, either on apices of 2nd and 3rd segments or alternate on 2nd segment (Fig. 4D,L) 13

10. Mandible with basal striations (Fig. 3A, arrowed). Body of larva generally with two pairs of ventral tubules and 1 pair of lateral tubules on posterior segments although some reduction may occur. . . . . *Chironomus*

Mandible lacking basal striations 11

11. Ventromental plates narrow, only c. 2× as wide as deep (Fig. 3F). Fenestra (Fig. 3G, arrowed) may be present . . . . . *Dicrotendipes*

Ventromental plates broad, at least 2.5× as wide as deep (Fig. 3K) 12

12. Premandible (*pmd*) with at least 5 teeth (Fig. 4B, arrowed). Fenestra (as in Fig. 3G) on anterior frons . . *Kiefferulus*

Premandible with 2-3 teeth. Frons without fenestra . . . . . *Polypedilum*

13. Apical segment of antenna elongate, whip-like (Fig. 5D). All mental teeth pale (Fig. 5E) . . unknown genus 'K2'

Antennal apical segments conventionally short, not whip-like (Fig. 4D). Median mentum paler than lateral teeth, or evenly darkened. 14

14. Median part of mentum pale (Fig. 4C) . . *Microtendipes*

Median mentum dark 15

15. Uneven number of subequal mental teeth (Fig. 5A) . . . . . *Stictochironomus*

Even number of disparate-sized mental teeth (Fig. 3D) . . . . . *Conochironomus*

16. Mentum concave with pale median tooth (Fig. 3E) . . . . . *Cryptochironomus*

Mentum conventionally convex 17

17. Mentum with outermost group of 3 teeth forming group distinctively set-off from general slope (Fig. 3C) . . . . . *Cladopelma*

Mentum generally with teeth decreasing evenly in height from median to outermost 18

18. Median teeth of mentum dark, no wider than any lateral teeth. Anterior margin of ventromental plate crenulate (Fig. 4F, arrowed) . . . . . *Parachironomus*

Median teeth of mentum pale, broader than outermost teeth. Anterior margin of ventromental plate smooth (Fig. 3I). . . . . *Harnischia*

DISCUSSION

The total chironomid fauna of each Atherton Tableland lake (Barrine – 22 species, Eacham – 28 species and Euramoo – 12 species) is appreciably richer than assessed previously by larval benthic sampling (e.g. Timms, 1979). Lower numbers such as those based on grab-sampled benthos alone, gave rise to a belief that Australian lakes were species-poor relative to elsewhere. However, as observed by Wright & Cranston (2000), exuvial sampling consistently demonstrates a more complex system, certainly including littoral taxa and those living in obscure (and under-sampled) substrates such as immersed wood. The diversity of Lakes Eacham and Barrine lies at the high end of studied lakes in Australia (Wright & Cranston, 2000), which in turn are comparably diverse to all except natural eutrophic lakes elsewhere in the world. Although modern Lake Euramoo now appears to have fewer species, historically an additional 20 taxa have occurred there (represented by subfossils), many of which are present now in either or both Lakes Eacham and Barrine.

Ordination of the chironomid fauna of Lakes Barrine and Eacham with environmental variables showed a significant correlation with water and air temperatures (Dimitriadis & Cranston, 2001). Thus different historical assemblages of chironomids (as represented by preserved head capsules) could be taken to infer different past climates. The presence of *Zavreliella marmorata*, *Thienemanniella*, *Microchironomus*, *Riethia* and ?*Skusella* sp. only amongst subfossil assemblages may reflect such differences. Cumulative species diversity through accumulation in longer time slices (as in palaeo-reconstruction) can lead to perhaps misleading impressions of higher past diversity than does the modern 'snapshot'.

The modern biota described above tends to be northern Australian to Asian outside the immediate study area, with little evidence of Gondwanan (cool/mesotherm, southern-connected) taxa.

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LITERATURE CITED

COFFMAN, W.P., CRANSTON, P.S., OLIVER, D.R. & SÆTHER, O.A. 1986. Keys and diagnoses of the pupae of the subfamily Orthocladiinae (Diptera, Chironomidae). Entomologica Scandinavica Supplement 28: 147-296.

COHEN, A.S. 2003. Paleolimnology – the history and evolution of lake systems. (Oxford University Press: Oxford)

CRANSTON, P.S. 1996. Identification guide to the Chironomidae of New South Wales. AWT identification guide no. 1. Australian Water Technologies Pty Ltd, West Ryde.

1997. The Australian *Rheotanytarsus* Thienemann & Bause (Diptera: Chironomidae) revised, with emphasis on the immature stages. Invertebrate Taxonomy 11: 705-34.

2000a. Monsoonal tropical *Tanytarsus* van der Wulp (Diptera: Chironomidae) reviewed: new species and life histories and aquatic environmental indicator significance. Australian Journal of Entomology 39: 138-159.

2000b. Electronic Guide to The Chironomidae of Australia. http://entomology.ucdavis.edu/chiropage/index.html

CRANSTON, P.S., WEBB, C.J. & MARTIN, J. 1990. The saline nuisance chironomid "*Carteronica*" *longilobus* (Diptera: Chironomidae): a systematic reappraisal. Systematic Entomology 15: 401-32.

CRANSTON, P.S. & HARE, L. 1995. *Conochironomus* Freeman: an Afro-Australian Chironomini genus revised (Diptera: Chironomidae). Systematic Entomology 20: 247-64.

DIMITRIADIS, S. & CRANSTON, P.S. 2001. An Australian Holocene climate reconstruction using Chironomidae from a tropical volcanic maar lake. Palaeogeography, Palaeoclimatology, Palaeoecology 176: 109-131.

EKREM, T. 2001. Diagnoses and immature stages of some Australian *Tanytarsus* van der Wulp (Diptera: Chironomidae). Australian Journal of Entomology 40: 312-325.

FREEMAN, P. 1961. The Chironomidae (Diptera) of Australia. Australian Journal of Zoology 9: 611-737.

HARDWICK, R.A., COOPER, P.D., CRANSTON, P.S., HUMPHREYS, C.L. & DOSTINES, P.L. 1995. Spatial and temporal distribution patterns of drifting pupal exuviae of Chironomidae (Diptera) in streams of tropical northern Australia. Freshwater Biology 34: 569-578.

KOWALYK, H.E. 1985. The larval cephalic setae in the Tanypodinae (Diptera: Chironomidae) and their importance in generic determinations. Canadian Entomologist 117: 67-106.

RIERADEVALL, M. & BROOKS S.J. 2001. An identification guide to subfossil Tanypodinae larvae (Insecta : Diptera : Chironomidae) based on cephalic setation. Journal of Paleolimnology 25(1): 81-99.

ROBACK, S.S. 1982a. The immature stages of some Australian Tanypodinae (Diptera), with some notes on the adults. Journal of the Australian Entomological Society 21: 147-160.

1982b. The Tanypodinae (Diptera: Chironomidae) of Australia II. Proceedings of the Academy of Natural Sciences of Philadelphia 134: 80-112.

SÆTHER, O.A. & SUNDAL, A. 1999. *Cerobregma*, a new subgenus of *Polypedilum* Kieffer, with a tentative phylogeny of subgenera and species groups within *Polypedilum* (Diptera: Chironomidae). Journal of the Kansas Entomological Society 71: 315-382.

TIMMS, B.V. 1979. The Benthos of some lakes in Northeastern Queensland. Proceedings of the Royal Society of Queensland 90: 57-64.

VEIJOLA, H., MERILÄINEN, J.J. & MARTILLA, V. 1996. Sample size in the monitoring of benthic macrofauna in the profundal of lakes: evaluation of the precision of estimates. Hydrobiologia 322: 301-315.

WALKER, D. 1999. Some physical and chemical features of two upland crater lakes in tropical north-eastern Australia. Marine and Freshwater Research, 50: 159-177.

WALKER, I.R. 1987. Chironomidae (Diptera) in paleoecology. Quaternary Science Reviews 6: 29-40.

2001. Midges: Chironomidae and related Diptera. Pp. 43-66. In Smol, J.P., Birks, H.J.B. & Last, W.M. (eds) Tracking environmental change using lake sediments. Volume 4: Zoological Indicators. (Kluwer Academic Publishers: Dordrecht).

WIEDERHOLM, T. (ed.) 1983. Chironomidae of the Holarctic region. Keys and Diagnoses. Part 1. Larvae. Entomologica Scandinavica Supplement 19: 1-457.

WRIGHT, I. & CRANSTON, P.S. 2000. Are Australian lakes different? Chironomid and chaoborid exuviae from Lake McKenzie, a coastal temperate dune lake. Internationale Vereinigung für Theoretische und Angewandte Limnologie Verhandlungen 27: 303-308.

DIVERSITY AND DISTRIBUTION OF THE VERONICELLIDAE (GASTROPODA: SOLEOLIFERA) IN THE ORIENTAL AND AUSTRALIAN BIOGEOGRAPHICAL REGIONS

S.R. GOMES AND J.W. THOMÉ

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We present the known diversity and distribution of Veronicellidae in the Oriental and Australian biogeographical regions. Material from several museums was used (Gomes & Thomé, 2001). The 13 species identified are: *Filicaulis bleekeri* (Keferstein, 1865), *Laevicaulis alte* (Férussac, 1821), *Sarasinula plebeia* (Fischer, 1868), *Semperula birmanica* (Theobald, 1864), *Se. carusi* (Simroth, 1893), *Se. insularis* Thomé (1983), *Se. maculata* (Templeton, 1858), *Se. parva* (Heynemann, 1885), *Se. tailandensis* Thomé et al., 1994, *Se. wallacei* (Issel, 1874), *Valiguna flava* (Heynemann, 1885), *Vl. siamensis* (Martens, 1867) and *Veronicella cubensis* (Pfeiffer, 1840). *Semperula* is mainly concentrated in the Australian region. *Se. maculata, Se. parva* and *Se. wallacei* are found in the Australian region, close to the Wallace line, with the exception of the latter which can also be found on the island of Upolu, much further to the east. *Se. insularis* is only recorded in the Christmas islands (Australia). *L. alte* and *Sa. plebeia* have the widest distribution, being found in both the Oriental and Australian regions. *F. bleekeri* and *V. flava* are restricted to a few Indonesian islands, near the Wallace line, while there are records of *Vl. siamensis* in Thailand and Sri Lanka. *Ve. cubensis* is recorded only in Hawaii and Guam, in the Australian region. ❑ *Mollusca, Soleolifera, Veronicellidae, distribution, Australian region, Oriental region.*

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The Veronicellidae Gray, 1840, has a tropical and subtropical distribution. It comprises land slugs totally devoid of shells, with a thick mantle (tegument), arched body and separate male and female genital pores, the former located anteriorly, under the right tentacle, and the other located medially, in the middle of the right hyponotum. They are well known throughout the world due to medical and economic importance of some species (Gomes & Thomé, 2001).

In the Oriental and Australian biogeographical regions (Fig. 1) the group has been the subject of considerable study, especially from 1821 to 1925. In this period more than 70 species were proposed, the descriptions based mainly upon colouration and morphology. Only occasionally did the descriptions contain general aspects of anatomy, where the greater part of the diagnostic characteristics of Veronicellidae is found.

Despite criticism from some authors (Baker, 1925; Thomé, 1975b), Grimpe & Hoffmann (1925a,b) and Hoffmann (1925) contributed considerably to knowledge of the Veronicellidae in these regions. They reassembled practically the entire synonymy of the Veronicellidae, furnishing important data about the systematic, distribution and morphology of 7 species, each of which featured a long synonymic list. Species from these regions have also been studied by Forcart (1969, 1973), Bishop (1977), Thomé (1983, 1992), Thomé et al. (1994) and Gomes & Thomé (2001).

We aim to ascertain the current diversity and distribution of the Veronicellidae in the Oriental and Australian biogeographical regions for comparisons with the patterns of diversity found in the Neotropical and Ethiopian regions (Thomé, 1975a,b, 1988c, 1989, 1993b; Thomé et al., 1997; Forcart, 1953, 1963, 1967, 1969, 1973).

MATERIALS AND METHOD

Original descriptions, together with later characterisations and notes referring to the proposed species of Veronicellidae from the Oriental and Australian biogeographical regions were analysed. Type material in the Senckenberg Museum (SMF) (Frankfurt, Germany) (6 lots, 13 specimens), the Natural History Museum (BMNH) (London) (2 lots, 10 specimens) and Museu de Ciências e Tecnologia da PUCRS (MCP) (Porto Alegre, Brazil) (3 lots, 38 specimens) were examined. Data referring to 102 lots of Veronicellidae from diverse locations in the Oriental and Australian regions, previously

FIG. 1. Biogeographical regions according to Wallace (Cox, 2000).

examined and identified by Gomes & Thomé (2001), was considered. This material came from the Australian Museum (AM) (Sydney) (58 lots, 202 specimens), Field Museum of Natural History (FMNH) (Chicago) (25 lots, 119 specimens), Museu de Ciências Naturais da Fundação Zoobotância do Rio Grande do Sul (FZB) (Porto Alegre) (4 lots, 42 specimens) and the Muséum National d'Histoire Naturelle (MNHN) (Paris) (15 lots, 37 specimens). Specimens were dissected as described by Thomé & Lopes (1973).

The species described as synonyms were those whose types were examined and (or) whose descriptions and re-descriptions furnished sufficient anatomical detail. In those cases where this was not possible, objective synonyms proposed by Hoffmann (1925) and Grimpe & Hoffmann (1925a,b), were accepted and considered in the survey of registered occurrences. Synonyms from beyond the study area were not taken into synonymy of the species.

Localities mentioned conform to their present designations, according to The Times Atlas of the World (1994) and Debenham (1978).

RESULTS AND DISCUSSION

Filicaulis bleekeri (Keferstein, 1865)

Veronicella (Vaginulus) bleekeri Keferstein, 1865: 118-126.
Meisenheimeria (Vanigula) bleekeri Grimpe & Hoffmann, 1925a: 387.
Vanigula bleekeri Hoffmann, 1925: 135-137, 231-232; Grimpe & Hoffmann, 1925b: 8, 13-14, 23.
Filicaulis bleekeri Baker, 1925: 14; Hoffmann, 1927: 18-19.

Filicaulis bleekeri was proposed from Java (Indonesia), under the designation *Veronicella (Vaginulus) bleekeri* by Keferstein (1865). The original description is a relatively detailed anatomical study that includes descriptions of the radula and jaw. Grimpe & Hoffmann (1925a) proposed *Vanigula* as a subgenus of *Meisenheimeria* Grimpe & Hoffmann, 1924 and included within it *Ve. bleekeri*. Hoffmann (1925) raised *Vanigula* to generic status at same year it was synonymised by Baker (1925) with *Filicaulis* Simroth, 1913. Hoffmann (1927) confirmed this synonymisation.

DISTRIBUTION OF *F. BLEEKERI*. Ambon, Anambas, Banda, Bornéo, Java, Sumatra (Indonesia) and Bangkok (Thailand) (Hoffmann, 1925; Grimpe & Hoffmann, 1925a,b).

The genus *Filicaulis* is also found in islands that form part of the Ethiopian biogeographical region (Comores, Madagascar e Seychelles) where, according to Forcart (1953), two other species are found.

Laevicaulis alte (Férussac, 1821)

Vaginulus alte Férussac, 1821: 14.
Vaginula alte Fischer, 1871: 157.
Vaginula maculosa Hasselt, 1830: 968; Semper, 1885: 325-326.
Vaginula frauenfeldi Semper, 1885: 324.
Vaginula leydigi Simroth, 1889: 552; Simroth, 1891: 861-906.
Veronicella willeyi Collinge, 1900: 431-434.
Vaginula leydigi celebensis Simroth, 1918: 282.
Vaginula leydigi keyana Simroth, 1918: 282.
Meisenheimeria alte Grimpe & Hoffmann, 1925a: 362-406; Hoffmann, 1925: 120-129; Grimpe & Hoffmann, 1925b: 8-13.
Laevicaulis alte, Baker, 1925: 18; Hoffmann, 1927: 3,18; Cowie, 1997: 38; Cowie, 1998: 38.

Laevicaulis alte was the first species of Veronicellidae proposed for the Oriental region. It was described by Férussac (1821) based upon material from Pondichery (India) as *Vaginulus alte*. *Vaginulus* Férussac, 1821 was improperly altered to *Vaginula* Berthold, 1827 (Thomé et al., 1997). From which point, *L. alte*, together with other species of Veronicellidae, were referred to as belonging to *Vaginula*. Grimpe & Hoffmann (1925a,b) included *L. alte* in *Meisenheimeria* Grimpe & Hoffmann, 1924 that was synonymised by Baker (1925) with *Laevicaulis* Simroth, 1913, which was accepted by Hoffmann (1927). Today, *L. alte* is well characterised and much is known of its anatomy, systematic, distribution and biology (Fischer, 1871; Grimpe & Hoffmann, 1925a,b; Forcart, 1953; Raut & Mandal, 1984; Raut & Panigrahi, 1988, 1989; Panigrahi & Raut, 1992; Thomé et al., 1997; Thomé et al., 2001). Gomes & Thomé (2001) examined lots of *L. alte* from Oriental and Australian regions, adding new morphological and anatomical characteristics.

Although, in the original study *Vaginula maculosa* Hasselt, 1830, was described from Java (Indonesia), there is only a brief characterisation of the morphology and colouration, the samples were later re-examined by Semper (1885). He outlined the structures used to identify the species of Veronicellidae at that time (external colouration, position of the female genital pore, penis and penial gland). Semper (1885) proposed *Va. frauenfeldi* based on material from Madras (India), the anatomical description was the same as that for *Va. maculosa*. His descriptions and illustrations of these two species coincide perfectly with those for *L. alte*. Moreover, *L. alte* is found in Indonesia as well as India.

Simroth (1889), based upon morphological and anatomical characteristics proposed *Va. leydigi,* for Brisbane. Simroth (1891) added detailed descriptions of the reproductive, nervous and digestive systems, and included comparative histological studies of two other species found in the Oriental and Australian regions. Simroth (1918) upon finding *Va. leydigi* in Sulawesi and the Kay Islands, proposed *Va. leydigi celebensis* and *Va. leydigi keyana*. The specimens, according to the author, presented variations in size of the penis, number of gland tubules and intensity of colouration when compared to the original species. According to the system of Veronicellidae currently in use, Simroth's (1889) subspecies are not valid, given that variations of this type are often found in Veronicellidae, between different populations and even within the same population (Martins, 1998; Soares & Thomé, 2002; Gomes & Thomé, 2001, 2002). *Va. leydigi* is a synonym of *L. alte* according to Simroth (1889). Only two species of Veronicellidae are found in Australia, *L. alte* and *Sa. plebeia*, both well known (Burch, 1976; Bishop, 1977; Smith, 1984).

Paratypes of *Veronicella willeyi* from Lifou (New Caledonia), proposed by Collinge (1900) and deposited in the Natural History Museum (BMNH-1905.4.12.9-10), were examined and the anatomy corresponds to that of *L. alte*.

DISTRIBUTION. Moa, Murray, Thursday Islands (Torres Strait), Cardwell, Cooktown, Lismore, Mission Beach, Rockhampton, Yeppoon, NorthWest island (Queensland), Hong Kong, (China), Viti Levu (Fiji), Midway, Molokai, Oahu, Honolulu, Havaí (Hilo, Kailua) (Hawaii), Andaman, Madras, Pondichery (India), Ambon, Bali, Banda, Java, Kai, Halmahera (Ternate), New Guinea (Sarmi), Sulawesi (Raha), Sunda, Timor Timur (Tenimber), (Indonesia), Pinang (Malaysia), Bourail, Koné, Lifou, Nouméa, Maré, Oubatche, Ouvéa (New Caledonia), Manila, Mindanao (Philippines), Takao, Auping (Taiwan), Éfaté, Espiritu Santo (Vanuatu) and Upolu (Western Samoa) (Grimpe & Hoffmann, 1925a,b; Hoffmann, 1925, 1927, 1930; Forcart, 1969, 1973; Bishop, 1977; Thomé, 1989; Cowie, 1997, 1998; Thomé et al., 1997; Gomes & Thomé, 2001). Gomes & Thomé (2001) first registered the species in Fiji, Malaysia and New Guinea.

Laevicaulis occurs in Africa where, 8 species occur, among them *L. alte*, the only species of the genus found outside the African continent (Forcart, 1953). The species has recently been registered in the Bermudas and Texas (U.S.A) (Thomé, 1989; Thomé et al., 1997).

Sarasinula plebeia (Fischer, 1868)

Vaginulus plebeius Fischer, 1868: 146; Thomé, 1971: 34-36.
Vaginula andreana Semper, 1885: 321.
Veronicella hedleyi Simroth, 1889: 552; Simroth, 1918: 861-906.
Vaginula levucana Simroth, 1918: 262-290.
Vaginula samoana Simroth, 1918: 290-291.
Vaginula tahitiana Simroth, 1918: 290-292.
Sarasinula plebeja Grimpe & Hoffmann, 1924: 177; Grimpe & Hoffmann, 1925a: 19-26; Hoffmann, 1925: 190, 251-252; Grimpe & Hoffmann, 1925b: 344-406; Thomé, 1975b: 25-27.
Imerinia plebeja Baker, 1925; Hoffmann, 1934: 259-260.
Vaginula plebeia Cowie, 1997: 38.
Vaginulus (Sarasinula) plebeius Forcart, 1969: 149-150; Aguayo, 1964; Forcart, 1973; Cowie, 1998.
Sarasinula plebeia Thomé, 1975b: 25-27; Gomes & Thomé, 2001: 141-143; Gomes & Thomé, 2002.

Sarasinula plebeia was originally assigned to *Vaginulus* Férussac, 1821 based upon a drawing received by the senior author from correspondents in Nouméa (New Caledonia). The species served as a base for *Sarasinula* Grimpe & Hoffmann, 1924, synonymised with *Imerinia* Cockerell, 1891 by Baker (1925) and Hoffmann (1934). Thomé (1971), after having examined 3 specimens from New Caledonia, in the Muséum National d'Histoire Naturelle (Paris), chose one to be a plesiotype. Thomé (1975b), in his revision of the Veronicellidae in the Neotropical region, considered *Sarasinula* valid. Gomes & Thomé (2001, 2002) examined specimens of *Sa. plebeia* from various localities of the regions under study, including New Caledonia. Based on this material they re-described, in detail, the anatomy of the species and assessed the intraspecific variability between species originating from 7 countries of the Australian region.

Following examination of the types of *Vaginula andreana* Semper, 1885 from Mauritius, Thomé (1988b) revalidated the species in *Sarasinula*. Prior to this, Hoffmann (1925) had considered the species a synonym of *Sa. plebeia*. Assessing the anatomical descriptions of *Va. andreana* performed by these authors and considering the morphological variability of *Sa. plebeia* in the Australian region (Gomes & Thomé, 2002) it is verified that the synonymy suggested by Hoffmann (1925) be maintained.

Simroth (1889) proposed *Va. hedleyi*, taking into consideration morphological and anatomical characteristics of material from Brisbane (Australia). After comparing the two species from the region, Simroth (1891) re-described the species, furnishing data, including histological sections, on the reproductive, nervous and digestive systems of *Va. hedleyi*. From these descriptions and illustrations we confidently include this species in the synonymy of *Sa. plebeia*.

Simroth (1918) upon analysing veronicellids from various Pacific Ocean islands, proposed various species, in general, differentiated by inconsistent and invalid details, such as colouring and minimal differences in the position of the female genital pore and number of gland tubules. Among these, *Va. levucana* (type locality: Viti Levu, Fiji), *Va. samoana* (type locality: Apia, Western Samoa) and *Va. tahitiana* (type locality: Papeete, Tahiti), are all synonyms of *Sa. plebeia*. As well as the original descriptions, paratypes of *Va. samoana* (SMF-45245/3), *Va. levucana* (SMF: 45239/4) and the holotype of *Va. tahitiana* (SMF-45246/1) were examined.

DISTRIBUITION. Atherton, Brisbane, Cairns, Cardwell, Cooktown, Gladstone, Innisfai, Lismore, Proserpine, Rockhampton, Saint George, Sarina, Townsville, Repulse Bay (Queensland), Grafton, Muswelbrook, Clarence (New South Wales), Darwin (North Territory), Bau, Levuka, Viti Levu (Fiji), Hawaii, Oahu (Hawaii), Ambon, Halmahera, Sumatra (Toba) (Indonesia), Guam, Saipan (Marianas), Bourail, Canala, Ilha dos Pins, Koné, Lifou, Maré, Nouméa, Oubatche, Ouvéa, Yaté (New Caledonia), Leyte, Manila (Philippines), Bougainville (Salomon Islands), Papeete, Tipaerui Valley (Tahiti), Tonga island, Mangareva (Tuamotu), Aoba, Malakula, Malo, Efate, Espiritu Santu (Vanuatu) and Apia, Savai'i, Upolu (Western Samoa) (Grimpe & Hoffmann, 1925a,b; Hoffmann, 1925, 1927, 1934; Forcart, 1969, 1973; Bishop, 1977; Cowie, 1997, 1998; Gomes & Thomé, 2001). Gomes & Thomé (2001) first registered the species in New South Wales and the Northern Territory (Australia), the Solomon Islands, Tonga and Tuamotu.

Sarasinula Grimpe & Hoffmann (1924) occurs in the Neotropical, Australian and Ethiopian regions (Madagascar and the Comoros). This appears to form a natural group of species, relatively close in evolutionary terms and consequently similar morphologically. Due to this, there is still no consensus as to how many are valid species (Gomes & Thomé, 2002).

Semperula birmanica (Theobald, 1864)

Vaginulus birmanicus Theobald, 1864: 243-244.
Vaginula birmanica Tapperoni-Canefri, 1889: 337-338.
Semperula birmanica Grimpe & Hoffmann, 1925a: 338, 394; Hoffmann, 1925: 182-186, 254-255; Grimpe & Hoffmann, 1925b: 8, 17, 36-38; Thomé et al., 1994: 597.

Semperula birmanica was proposed by Theobald (1864), based upon specimens from Rangoon (Burma). It was originally included in *Vaginulus*. Hoffmann (1925) did not examine the holotype, but found material from museums in Viena and Berlin that Tapperoni-Canefri (1889) identified and described as this species. Even though he did not have anatomical descriptions, based upon morphological descriptions Hoffmann (1925) concluded that the authors were dealing with the same species. Based upon this material, Hoffmann (1925) described, in general the anatomy of *Va. birmanica*, and included it in *Semperula*.

The species is similar to *Se. maculata*, although, when examined closely and described by Grimpe & Hoffmam (1925a) and Hoffmann (1925), the penis, considered the principal specific diagnostic feature of Veronicellidae, exhibits a 'honeycomb' aspect with a turned up 'fingerlike' projection, which is relatively characteristic. Thomé et al. (1994), upon proposing a new species of *Semperula*, considered *Se. birmanica* a valid species from the original literature and subsequent citations.

DISTRIBUTION. Bhamo, Pegu, Rangoon, Tenasserim, Thayet-Myo (Burma), Hong Kong, Macau, Tonquim (China), Arrakan, Calcutta, Bengal, Sikkim (India), Bali, Java, Lombok, Sumatra (Padang) (Indonesia), Melaka, Pinang (Malaysia), Manila, Mindanao (Zamboanga), Samar, (Philippines) and Ho Chi Minh (Viet Nan) (Hoffmann, 1925, 1928, 1930; Grimpe & Hoffmann, 1925a,b).

Semperula Grimpe & Hoffmann, 1924, is restricted to the Oriental and part of the Australian biogeographical regions, where 7 valid species occur.

Semperula carusi (Simroth, 1893)

Vaginula carusi Simroth, 1893: 65-69.
Semperula carusi Thomé, 1992: 100-101.

Se. carusi was originally described from Singapore by Simroth (1893) who supplied important data on its morphology and anatomy. Hoffmann (1925) and Grimpe & Hoffmann (1925a,b), after analysing the type material, considered it a synonym of *Se. maculata*. However, Thomé (1992), after re-examining the lectotype and paralectotypes, in the Zoologisches Museum (Berlin, Germany), re-described and revalidated *Se. carusi* for having singularities that differentiate it from all the other anatomically known species of the genus.

DISTRIBUTION. Singapore (Simroth, 1893; Thomé, 1992).

Semperula insularis Thomé, 1983

Semperula insularis Thomé, 1983: 15-18.

Se. insularis Thomé, 1983 from Christmas Island (Australia) represents a valid species, with peculiar morphological characteristics.

DISTRIBUTION. Christmas Island (Thomé, 1983).

Semperula maculata (Templeton, 1858)

Vaginula maculata Templeton, 1858: 49-50; Semper, 1885: 322.
Vaginula hennigi Simroth, 1889: 552; Simroth, 1891: 861-906.
Semperula maculata Grimpe & Hoffmann, 1925a: 389-90, 392; Hoffmann, 1925: 175-9, 210-1, 258-60; Grimpe & Hoffmann, 1925b: 38-9; Hoffmann, 1927: 37; Hoffmann, 1930: 98-9; Hoffmann, 1934: 255-6; Thomé, 1992: 98-100.
Vaginula creophila Simroth, 1918: 261, 288-9; Hoffmann, 1941: 239-41.
Vaginula rufiglandula Simroth, 1918: 261, 283-4; Hoffmann, 1941: 237.
Vaginula rufiglandula rufescens Simroth, 1918: 261, 283; Hoffmann, 1941: 237.
Vaginula newtoni Simroth, 1893: 68-9.
Vaginula borneensis Simroth, 1897: 142-4.
Vaginula variegatula Simroth, 1918: 284.
Vaginula signata Simroth, 1918: 248.
Vaginula signata signatior Simroth, 1918: 284.
Vaginula svelana Simroth, 1918: 284.

Se. maculata, proposed by Templeton (1858) based upon material from Colombo (Sri Lanka), is not identifiable from the original description. Despite this, Semper (1885), attributed specimens to this species, describing the aspect of the penis, the penial gland and pedal nerves. The same structures were re-described by Grimpe & Hoffmann (1925a,b) and Hoffmann (1925), following the re-examination of Semper's (1885) specimens. Thomé (1992) redescribed *Se. maculata*, agreeing with the attributions proposed by Semper & Hoffmann (1925). Gomes & Thomé (2001) examined a lot originating from Kuala Lumpur (Malaysia), whose anatomy corresponded to that already known for *Se. maculata*. This material was used to augment the anatomy of *Se. maculata*.

Vaginula hennigi was proposed by Simroth (1889) from Cambodja (Thailand) and re-described in detail (Simroth, 1891). As with the other two species mentioned by Simroth (1889, 1891), *Va. hennigi* exhibits sufficient morphological, anatomical and histological descriptions for synonymisation.

Hoffmann (1930, 1941) validated *Va. variegatula* Simroth (1918) and *Va. signata* Simroth (1918) from Lombok, after analysing the type material of both; he included them in *Semperula*. The two species had been considered synonyms of *Se. maculata* by Hoffmann (1925). The fact of the penial opening is located 'a little' further forward and the small differences in the size and location of the female genital pore used by Hoffmann (1930, 1941) to propose revalidation, are not sufficient justification. Moreover, the samples used were juvenile, which naturally display differences in the shape of the reproductive structures. Therefore, these two species should remain as synonyms of *Se. maculata*. The same can be argued in relation to *Va. signata signatior* and *Va. svelana*, proposed by Simroth (1918) due to the variations of external colour. Holotypes of *Va. signata* (SMF-45226/1), *Va. svelana* (SMF-45220/1) and paratypes of *Va. signata* signatior (SMF-45231/3) were examined.

Thomé (1992) proposed *Va. creophila* and *Va. rufiglandula*, originally described by Simroth (1918) from Lombok and Sulawesi (Indonesia) respectively, as synonyms of *Se. maculata* and *Va. rufiglandula rufescens*, from the same location as the nominal species. Together with these, the synonymy also includes *Va. newtoni* Simroth, 1893, from Java and *Va. borneensis* Simroth, 1897 from Borneo (Indonesia). All these species are synonyms of *Se. maculata*, in accordance with criteria presented by Thomé (1992).

DISTRIBUTION. Luwu, Tonquim (China), Madras (India), Ambon, Bali (Gitgit), Banda, Borneu (Baram), Bogor, Flores, Halmahera (Ternate), Jakarta, Java, Lombok (Swela, Sadjang, Sapit), Manila, Nias, Salayar, Sumatra, Sulawesi, Sumbawa, (Pandang and Singkarak) (Indonesia), Singapore, Kuala Lumpur (Malaysia), Mindanao, Manila (Philippines), Colombo, Galle, Kandy, Ratnapura (Sri Lanka) and Bangkok, Cambodia (Thailand) (Hoffmann, 1925, 1927, 1930; Thomé, 1992; Gomes & Thomé, 2001).

Semperula parva (Heynemann, 1885)

Vaginula parva Heynemann, 1885: 89-90, 122-3.
Vaginula chavesi Simroth, 1893: 66.
Vaginula djiloloensis Simroth, 1897: 140-142, 144.
Semperula parva Thomé, 1992: 92-94, 100-101.

Se. parva was recorded in Indonesia and the Philippines due to a synonymy specified by Thomé (1992). After examining type material of species from this region, he proposed the revalidation of *Se. parva*, considering *Va. djiloloensis* Simroth (1897), from Halmahera (Indonesia) and *Va. chavesi* Simroth (1893), from Mindanao (Phillipines), as synonyms of the former. Based upon the original descriptions of the species and the argument presented by Thomé (1992), these synonymies are accepted. *Se. parva* was described from the Seychelles Islands (Indian Ocean) by Heynemann (1885), being considered a synonym of *Se. maculata* by Hoffmann (1925).

DISTRIBUTION. Halmahera (Indonesia) and Mindanao (Philippines) (Thomé, 1992).

Semperula tailandensis Thomé et al, 1994

Semperula tailandensis Thomé et al., 1994: 597-604.

Se. tailandensis was described by Thomé et al. (1994) from Salaya Nakhon (Thailand). The type material was re-examined by Gomes & Thomé (2001) who re-characterised the species. The species has sufficient anatomical characteristics to differentiate it within the Veronicellidae.

DISTRIBUTION. Salaya Nakhon (Thailand) (Thomé et al., 2001; Gomes & Thomé, 2001).

Semperula wallacei (Issel, 1874)

Vaginula wallacei Issel, 1874: 385.
Vaginula idae Semper, 1885: 321-322.
Vaginulus reinhardti Semper, 1885: 323.
Semperula wallacei Hoffmann, 1941: 329-324.
Semperula wallacei reinhardti Hoffmann, 1941: 231-233.
Semperula wallacei celebensis Hoffmann, 1941: 233.
Semperula wallacei boviceps Hoffmann, 1941: 233.
Semperula celebensis Forcart, 1973: 26.
Semperula reinhardti Thomé, 1988b: 65-67.
Semperula christmasis Thomé, 1983: 18-20.
Semperula solemi Forcart, 1969: 151-156.

Se. wallacei was proposed by Issel (1874) on an example from Sarawak (Borneo). Hoffmann (1925) and Grimpe & Hoffmann (1925a,b) considered *Se. wallacei* a synonym of *Se. idae* Semper (1885), ignoring the fact that the latter was proposed subsequently. Only later, did Hoffmann (1941), upon rediscovering Issel's holotype of the species that had been considered lost, correct his error, placing *Se. idae* in the synonymy of *Se. wallacei*, and describing the morphology and anatomy of some structures. Gomes & Thomé (2001) re-described the species, commenting on previously unknown anatomical features.

Vaginulus reinhardti was proposed by Semper (1885) based on material from Macao (China). Hoffmann (1925) and Grimpe & Hoffmann (1925a,b) considered it a synonym of *Se. idae* (= *Se. wallacei*). Grimpe & Hoffmann (1924) designated the latter as a type of *Semperula*. Hoffmann (1941), upon examining the juvenile paratype of *Vs. reinhardti*, decided to consider it a subspecies of *Se. wallacei*, based on different positions of the genital pore. Thomé (1988b) upon re-examining the holotype of the species, the penis of which was not with the specimen, considered it valid. Nevertheless, analysis of the descriptions furnished by the various authors, indicates that there are insufficient anatomical differences for such a validation. Therefore, we consider *Vs. reinhardti* as a synonym of *Se. wallacei*. In this later study from Hoffmann (1941), he erected *Se. wallacei celebensis* and *Se. wallacei boviceps*. These would be considered different from *Se. wallacei* due to the position of the 'papilla' of the right deferent vessel and the degree of demarcation of the circular nervure found in the penis of this species in the case of *Se. w. celebensis* and due to the colouring and position of female genital pore, in the case of *Se. w. boviceps*. However, these differences are not sufficient for them to be considered subspecies, given that such variations were verified by us within the different populations of *Se. wallacei* examined here. Thus, Hoffmann's (1941) two subspecies may be considered synonyms of *Se. wallacei*.

The types of *Se. solemi* (Forcart, 1969) from Espiritu Santo and Efate (Vanuatu) and lots from Indonesia (Ambon) and Western Samoa (Upolu), examined by Forcart (1973) and identified as *Se. wallacei celebensis*, were re-examined by Gomes

& Thomé (2001). They verified that the material was *Se. wallacei*.

Se. christmasis described by Thomé (1983) from Christmas Island, is also a synonym of *Se. wallacei*. This can be verified by analysis of the original descriptions and illustrations.

DISTRIBUTION. Christmas Island (Australia), Hong Kong, Macao (China), Viti Levu (Fiji), Ambon (Wasi), Borneo (Sarawak), Sulawesi (Parepare, Gimpu, Macasar), Sumatra (Tebingtinggi) (Indonesia), Upolu (Western Samoa) and Espiritu Santo, Efate (Vanuatu) (Grimpe & Hoffmann, 1925a,b; Forcart, 1969; Forcart, 1973; Gomes & Thomé, 2001). Gomes & Thomé (2001) first registered the species in Fiji and Western Samoa.

Valiguna flava (Heynemann, 1885)

Vaginula flava Heynemann, 1885: 10-11.
Vaginula schneideri Simroth, 1895: 7-8.
Semperula (Valiguna) schneideri Grimpe & Hoffmann, 1925a: 391-392.
Semperula siamensis schneideri Hoffmann, 1925: 181-182; Grimpe & Hoffmann, 1925b: 18-19, 31-33.
Valiguna schneideri Hoffmann, 1941: 236.
Valiguna isseli Hoffmann, 1941: 234.

Valiguna flava was proposed by Heynemann (1885) due to the morphological characteristics and colouring of a specimen from Borneo (Indonesia). That author also mentioned its occurrence at Nias and the western coast of Sumatra (Indonesia). Hoffmann (1925) and Grimpe & Hoffmann (1925a,b) considered *Vl. flava* a synonym of *Se. maculata*, without having examined the type material. We re-examined the holotype of *Vl. flava*, in the Natural History Museum (BMNH-1880.10.6.4). The species is relatively peculiar, especially with the regards anatomical characteristics. The penis has relatively specific dentate and lobular formations. Based upon this material the species is totally differentiated from *Se. maculata*.

Va. schneideri Simroth, 1895 is based upon material from the east of Sumatra (Indrapura, Tandjong Kuba). Grimpe & Hoffmann (1925a) proposed *Valiguna* as a subgenus of *Semperula*, considering *Va. schneideri* a type species. Hoffmann (1925) and Grimpe & Hoffmann (1925b) arrived at the conclusion it was a subspecies of *Se. siamensis*, disregarding *Valiguna*. Hoffmann (1941), though, upon finding *Vl. isseli*, that he judged to be new, with morphological characteristics similar to those of *Va. schneideri* reconsidered the taxon *Valiguna*, and elevated it to genus level. To judge from the original description of *Va. schneideri* as well as the descriptions of Hoffmann (1925) and Grimpe & Hoffmann (1925a,b) the species is a synonym of *Vl. flava*. *Valiguna isseli* Hoffmann, 1941, based upon material from Borneo, appeared to be similar to *Va. schneideri*, but differed from the former mainly in its colouring and the position of the female genital pore. Therefore, there are insufficient characteristics to maintain it as a valid species and should be considered a synonym of *Vl. flava*.

DISTRIBUTION. Borneo, Nias and Sumatra (Indrapura) (Indonesia) (Heynemann, 1885; Simroth, 1895).

Valiguna siamensis (Martens, 1867)

Vaginulus siamensis Martens, 1867: 68.
Vaginulus reticulatus Westerlund, 1883: 49; Thomé, 1984: 29-32.
Semperula siamensis Grimpe & Hoffmann, 1925a: 388, 390-391; Hoffmann, 1925: 179-181, 256-257; Grimpe & Hoffmann, 1925b: 8, 17-19, 44-47.

The description of *Vaginulus siamensis* made by Martens (1867), based upon material from Petshaburi (Thailand) is quite short, referring to the morphological characteristics and external colouring. Later, the holotype in the Berlin museum, was re-examined by Hoffmann (1925) who, described general aspects of the anatomy of the species. Grimpe & Hoffmann (1925a,b) and Hoffmann (1925) included *Vs. siamensis* in *Semperula*. They describe the relatively unusual aspect of the penis that has, on its convex side structures in the form of crests. Here, it is proposed that *Vl. siamensis* be included in *Valiguna*, together with *Vl. flava*, given that this type of formation, spines or crest-like accessories to the penis, only occurs in this species.

Grimpe & Hoffmann (1925a) proposed *Valiguna*, as a subgenus of *Semperula*, having *Vl. siamensis schneideri* as type species. *Valiguna* covers those forms in which the deferent vessel opens neither terminally (*acrocaulis*, as is the case of *Sarasinula*) nor basally (*pleurocaulis*, as is the case of *Semperula*), being intermediate to the two types (*acropleurocaulis* ou *pseudopleurocaulis*).

In the original description of *Vaginulus reticulatus* Westerlund, 1883 proposal based upon material from Galle (Sri Lanka) contains only a brief characterisation of the morphology and colouring. However, Thomé (1984) found, deposited in the Naturhistoriska Rikmuseet' in Stockholm (Sweden), syntypes of the species, which he used to describe in detail the anatomy of the species. The morphology and anatomy of *Vs.*

reticulatus coincide with that described by Grimpe & Hoffmann (1925a,b) and by Hoffmann (1925) for *Vl. siamensis*.

DISTRIBUTION. Galle (Sri Lanka) and Petshaburi (Thailand) (Martens, 1867; Thomé, 1984).

Veronicella cubensis (Pfeiffer, 1840)

Onchidium cubense Pfeiffer, 1840: 250.
Veronicella cubensis Thomé, 1993a: 113-120; Thomé et al., 1997: 531-532; Cowie, 1997: 39.

Veronicella cubensis was proposed by Pfeiffer (1840) from Cuba (Neotropical region). The original work consists of a brief commentary about the colouring. Hoffmann (1925) considered the species a synonym of *Belocaulus sloanei* (Cuvier, 1817). However, these two species were later re-described by Thomé (1988a, 1993a) based upon type materials, both being considered valid, the latter passed to *Veronicella*. Thomé (1993a), working on neotypes and paraneotypes, described in detail the morphology and anatomy of *Ve. cubensis*. He furnished a list of synonymic citations and registered the species for Hawaii (Oahu, Kalihi). Thomé et al. (1997) and Cowie (1997) mentioned the species for Hawaii. The morphology and anatomy of specimens from Guam (Mariana Islands) (MCP-6505, MCP-6506, MCP-6507) were found to coincide with that of *Ve. cubensis*.

DISTRIBUTION. Oahu (Hawaii) and Guam (Marianas Islands) (Cowie, 1977; Thomé, 1993a; Thomé et al., 1997).

Veronicella Blainville, 1817 is found in the Neotropical biogeographical region, where there are registers of 8 species, according to Thomé (1975, 1988a, 1993a).

CONCLUSIONS

Initial systematic studies of the Veronicellidae resulted in a large number of species being proposed in an arbitrary manner, based, in the majority of cases on variations in colour and small anatomical variations. Consequently, a large number of species are synonyms. It was possible to recognise 13 valid species of Veronicellidae, in 6 distinct genera (*Filicaulis*, *Laevicaulis*, *Sarasinula*, *Semperula*, *Valiguna* and *Veronicella*), in the Oriental and Australian regions. The majority of species have a distribution restricted to these regions, although they may also have constituents in the Ethiopian and Neotropical faunas.

Semperula stands out, as it includes the only species of the Veronicellidae family in which the penis has a deferent vessel opening in the basal or median position. The genus is represented by 7 species whose distribution is restricted to the Oriental and Australian regions (Fig. 2). *Se. birmanica*, *Se. carusi*, *Se. insularis*, *Se. tailandensis* and *Se. siamensis* are widely distributed in the Oriental region, but there are no registers in the Australian region. *Se. maculata*, *Se. parva* and *Se. wallacei* are also found in the Australian region, near Wallace's line. Only the latter, is found to the east, on the island of Upolu (Western Samoa).

F. bleekeri and *Vl. flava* have a restricted distribution, being found only on a few Indonesian islands close to Wallace's line, while *Vl. siamensis* is occurs in Thailand and Sri Lanka (Fig. 3).

L. alte and *Sa. plebeia* are the species with the widest distributions, being found in the Oriental as well as the Australian region (Fig. 3). Both are thought to have been introduced into these regions. The first appears to be of African origin (Ethiopian region) (Bruggen, 1981). The origin of *Sa. plebeia* remains unclear, although there is a consensus that it is a species that has been introduced into Australia and widely spread by commerce in the Indian and Pacific Oceans (Forcart, 1973; Burch, 1976; Bishop, 1977; Smith, 1984). It probably originated from American tropical regions, where it occurs from the Antilles to Chile (Thomé, 1987, 1997) given that there is no record of the genus in the Ethiopian and Oriental regions.

There are only two records of *Ve. cubensis* in the Australian region. It was introduced from Central America (Thomé, 1993a, 1997; Cowie, 1997).

In the Oriental and Australian regions the Veronicellidae occur naturally from South Asia to east of Wallace's Line (Hoffmann, 1925). These regions have a low diversity, when compared with South America where 18 genera of Veronicellidae are found (Thomé, 1975b). Bruggen (1986) suggested, in his comparison of the diversity of species found in the Neotropical and Ethiopian regions, that this may be the result of the competition for niches with other families of slugs and snails, such as Aperidae, Rathouisiidae and Urocyclidae, that are not found in the Neotropical region.

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LITERATURE CITED

AGUAYO, C.G. 1964. Notas sobre la distribucion de la babosa *Vaginulus plebejus*, Mollusca: Veronicellidae. Caribbean Journal of Science 4(4): 549-551.

BAKER, H.B. 1925. Nomenclature of Veronicellidae (Vaginulidae). Nautilus 39(1): 13-18.

BERTHOLD, A.A. 1827. Latreille's Natuerliche Familien des Thierreichs, aus dem Franzoesischen, mit Anmerkungen und Zusaessen. (Gr. H. S. priv. Landes-Industrie-Comptoirs: Weimar).

BISHOP, M.J. 1977. Terrestrial mollusca of Queensland: the family Veronicellidae. Memoirs of the Queensland Museum 18(1): 53-59.

BRUGGEN, A.C. van 1981. The African element among the terrestrial molluscs of the island of Madagascar. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen 84(1): 115-129.

1986. Aspects of the diversity of the land molluscs of the Afrotropical Region. Revue de Zoologie africaine 100: 29-45.

BURCH, J.B. 1976. Outline of classification of Australian terrestrial molluscs (native and introduced). Journal of the Malacological Society of Australia 3(3-4): 127-156.

COCKERELL, T.D.A. 1891. On the geographical distribution of slugs. Proceedings of the Zoological Society of London 14: 214-226.

COLLINGE, W.E. 1900. Report on the slugs. Pp. 429-438. In Willey, A. Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere collected during the years 1895, 1896 and 1897. (University Press: Cambridge).

COWIE, R.H. 1997. Catalog and bibliography of the nonindigenous nonmarine snails and slugs of the Hawaiian Islands. Bishop Museum Occasional Papers 50: 1-66.

1998. Catalog of the Nonmarine snails and slugs of the Samoan Islands. Bishop Museum Bulletin in Zoology 3: 1-122.

COX, C.B. & MOORE, P.D. 2000. Biogeography. An ecological and evolutionary approach. (Blackwell Science: Osney Mead).

CUVIER, G. 1817. Le Règne Animal distribué d'après son organization, pour servir de base a l'histoire naturelle des animaux et d'introduction a l'anatomie comparée. (Chez Deterville: Paris).

DEBENHAM, F. (ed.). 1978. Grande Atlas Mundial. (Reader's Digest: Lisboa).

FÉRUSSAC, D. 1821. Tableaux systématiques des animaux mollusques. Deuxième partie: tableau de la famille des Limaces. (Chez Arthus Bertrand: Paris).

FISCHER, P. 1868. Diagnoses de deux Limaciens de la Nouvelle Calédonie. Journal de Conchyliologie 16: 145-146.

1871. Révision des espèces du Genere Vaginula Férussac. Nouvelles Archives du Muséum d' Histoire Naturelle 7: 147-175.

FORCART, L. 1953. The Veronicellidae of Africa (Mollusca, Pulmonata). Annales du Musée du Congo Belge, Sciences Zoologiques 23: 1-110.

1963. Slugs of South Africa. Proceedings of the Malacological Society of London 35(2/3): 103-110.

1967. Studies on the Veronicellidae, Aperidae and Urocyclidae (Mollusca) of southern Africa. Annals of the Natal Museum 18(3): 505-570.

1969. Veronicellid land slugs from the New Hebrides, with description of *Semperula solemi*, new species. Fieldiana: Zoology 51(12): 147-156.

1973. Notes on Veronicellidae and Athoracophoridae in Field Museum of Natural History, Chicago. The Nautilus 87(1): 25-27.

GOMES, S.R. & THOMÉ, J.W. 2001. Anatomia comparada de cinco espécies da família Veronicellidae (Gastropoda, Soleolifera) ocorrentes nas regiões biogeográficas Australiana e Oriental. Biociências 9(2): 137-151.

2002. Variabilidade morfológica de *Sarasinula plebeia* (Fischer, 1868) (Veronicellidae; Gastropoda) na região Australiana. Acta Leopoldensia 24(1): 37-46.

GRAY, J.E. 1840. Synopsis of the contents of the British Museum. (G. Woodfall & Son: London).

GRIMPE, G. & HOFFMANN, H. 1924. Diagnosen neuer Athoracophoriden (Gastropoda, Pulmonata). Zoologische Anzeiger (68): 171-177.

1925a. Versuch einer Revision der indischen, indound polynesischen Vaginuliden (Gastrop. Pulm.). Zeitschrift fur wissenschaftliche Zoologie 124(1): 1-50.

1925b. Die Nacktschnecken von Neu-Caledonien, den Loyaty-Inseln und den Neuen-Hebriden. Pp. 339-476. In Sarasin, F. & Roux, R. (eds) Nova Caledônia, Zoologie. (C.W. Kreidel's: Berlin).

HASSELT, J.C. van 1830. Nouvelles additions a la famille des Limaces. Pp. 96^{1} a 96^{24}. In Férussac, D & Deshayes, G.P. (1819/1851). Histoire Naturelle Générale et Particulière des Mollusques terrestres et Fluviatiles. (Chez J.B. Baillière: Paris).

HEYNEMANN, D.F. 1885. Ueber Vaginula-Arten im British Museum (Natural-History) in London. Jahrbücher der Deutschen Malakozoologischen Gesellschaft 12: 1-16.

HOFFMANN, H. 1925. Die Vaginuliden. Ein Beitrag zur Kenntnis ihre Biologie, Anatomie, Systematik, geographischen Verbreitung und Phylogenie. Jenaische Zeitschrift für Naturwissenschaft 61(1/2): 1-374.

1927. Über Vaginuliden aus dem Reichsmuseum Stockholm. Arkiv för Zoologi 19A(25): 1-39.

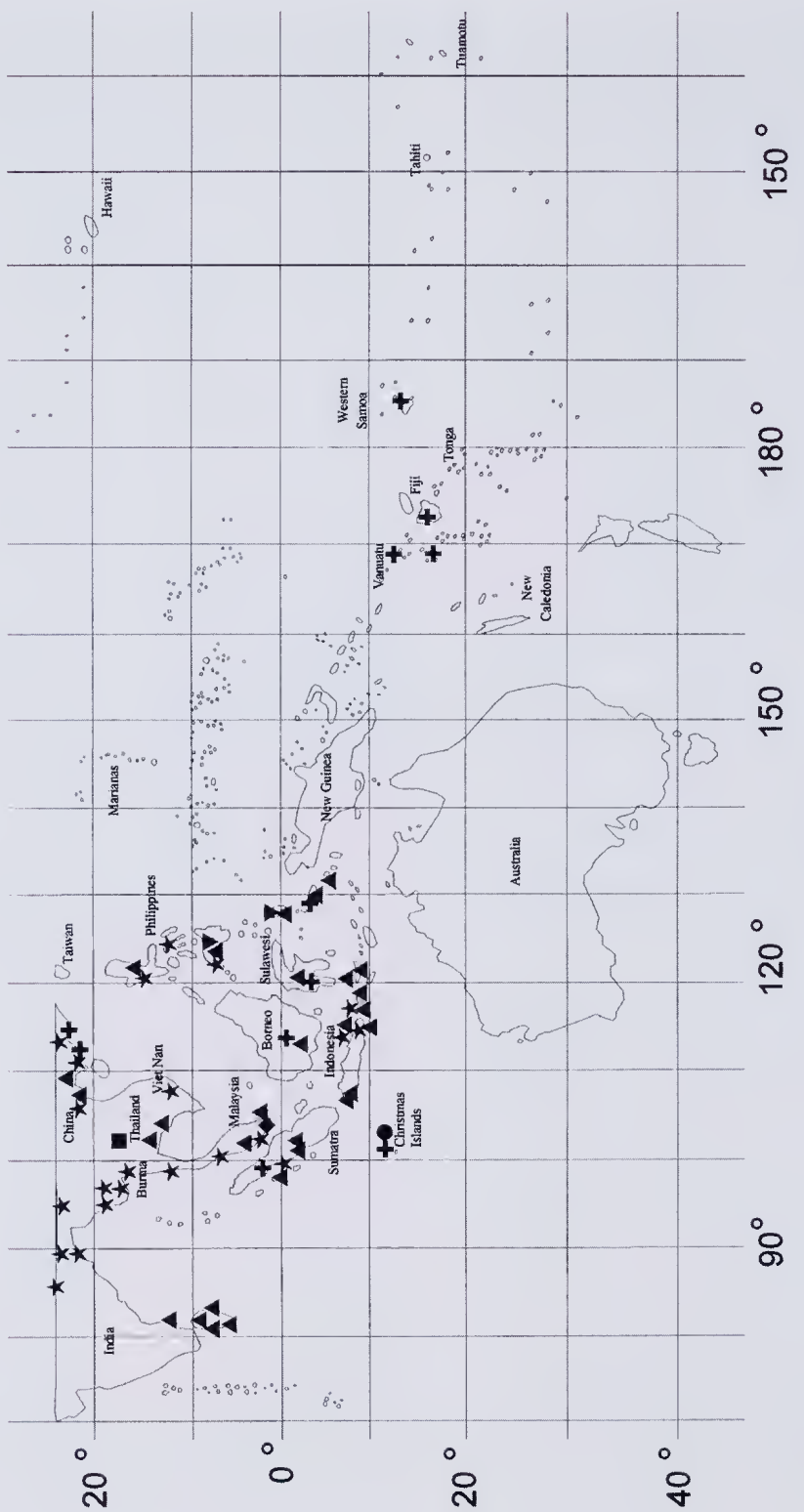

FIG. 2. Distribution of *Se. birmanica* (★), *Se. carusi* (◆), *Se. insularis* (●), *Se. maculata* (▲), *Se. parva* (▼), *Se. tailandensis* (■) and *Se. wallacei* (✚) in the Oriental and Australian biogeographical regions.

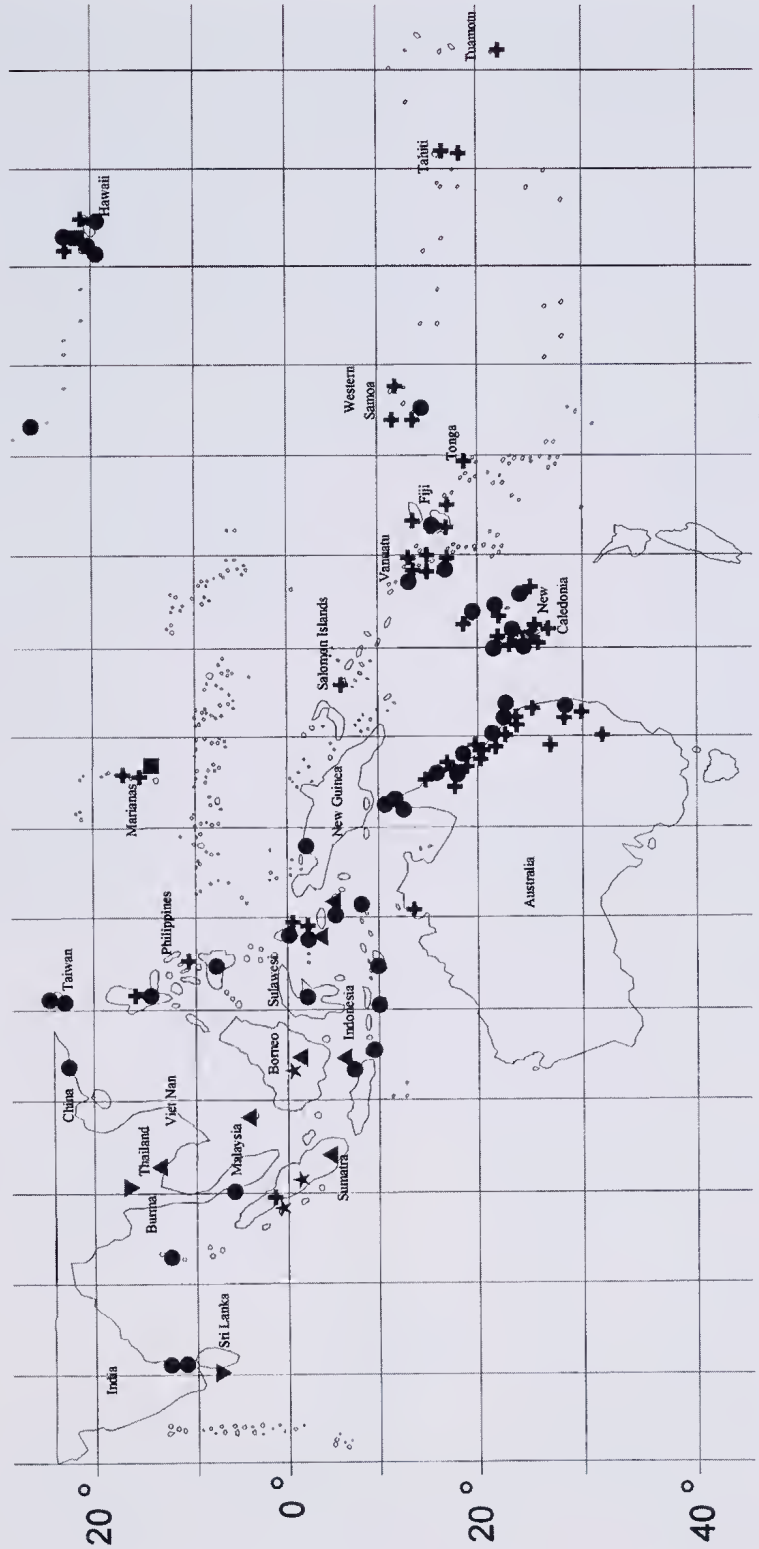

FIG. 3. Distribution of *F. bleekeri* (▲), *L. alte* (●), *Sa. plebeia* (✚), *Vl. flava* (★), *Vl. siamensois* (▼) and *Ve. cubensis* (■) in the Oriental and Australian biogeographical regions.

1928. Ueber einige Vaginuliden. Archiv für Molluskenkunde 60: 244-251.

1930. Die Vaginuliden der Sunda-Expedition Rensch. Zoologischer Anzeiger 88 (5/6): 97-110.

1934. Nacktschnecken und Halbnacktschnecken von Java und Sumatra. Archiv für Hydrobiologie 5: 255-291.

1941. Über einige Vaginuliden auf Grund bisher für verschollen gehaltener Typstücke. Zoologischer Anzeiger 136: 229-242.

ISSEL, A. 1874. Molluschi Borneensi. Annali del Museo civico di Storia naturelle di Genova 6: 366-486.

KEFERSTEIN, W. 1865. Anatomische Untersuchung von *Veronicella (Vaginulus) bleekeri* n. sp. Zeitschrift für Wissenschaftliche Zoologie 15(1): 118-126.

MARTENS, E. von 1867. Die Preussische Expedition nach Ost-Asien. Nach amtlichen Quellen. Zoologischer Theil, II. Band: die Landschnecken. (Königlichen Geheimen OberHofbuchdrückerei: Berlin).

MARTINS, R.S. 1998. Aspectos da morfologia e biometria de cinco formas de *Phyllocaulis soleiformis* (Orbigny, 1835). (Unpubl. Dissertação de Mestrado, Pontifícia Universidade Católica do Rio Grande do Sul: Porto Alegre).

PANIGRAHI, A. & RAUT, S.K. 1992. Influence of temperature and food on the growth of the pestiferous slug *Laevicaulis alte* (Soleolifera: Veronicellidae). Walkerana 6(16): 219-235.

PFEIFFER, L. 1840. Übersicht der im Januar, Februar und März 1839 auf Cuba gesammelten Mollusken. Archiv für Naturgeschichte 6(1): 250-261.

RAUT, S.K. & MANDAL, N. 1984. Natural history of the garden slug *Laevicaulis alte*. Journal of Bengal Natural History Society 3(1): 104-105.

RAUT, S.K & PANIGRAHI, A. 1988. Eggs-nesting in the garden slug *Laevicaulis alte* (Férussac) (Gastropoda: Soleolifera). Malacological Rewiew 21: 101-107.

1989. Diseases of Indian pest slugs and snails. Journal of Medical and Applied Malacology 1: 113-121.

SEMPER, C. 1885. Landmollusken. Pp. 291-327. In Reisen im Archipel der Philippinen. (C.W. Kreidel's: Wiesbaden).

SIMROTH, H. 1889. Ueber einige Vaginula-Arten. (Vorlaeufige Mittheilung). Zoologischer Anzeiger 12(319): 551-556.

1891. Ueber einige Vaginula-Arten. Zoologischen Jahrbüchern 5: 861-906.

1893. Einen Nachtrag zu seinem Berichte über die Vaginuliden (von 10). Sitzungsberichte der Naturforschenden Gesellschaft 17/18: 84-86.

1895. Eine neue Vaginula-Species: *Vaginula schneideri* n. sp. Sitzungsberichte der Naturforschenden Gesellschaft 19/21: 7-8.

1897. Nacktschnecken aus dem Malayischen Archipel. Senckenbergischen Naturforschenden Gesellschaft 24(201): 137-144.

1913. Ueber die von Herrn Prof. Voeltzkow auf Madagaskar und in Ostafrika erbeuteten Vaginuliden, nebst verwandtem Material von ganz Afrika. Pp. 127-216. In Voeltzkow, A. Reise in Ostafrika in den Jahren 1903-1905 mit Mitteln der Hermann und Elise geb. Heckmann Wentzel-Stiftung ausgeführt. (E. Schweizerbart'sche Verlagsbuchhandlung: Stuttgart).

1918. Über einige Nacktschnecken vom Malayischen Archipel von Lombok an ostwaerts bis zu den Gesellschafts-Inseln. Senckenbergischen Naturforschenden Gesellschaft 35(335): 261-306.

SMITH, B.J. 1984. Regional endemism of the south-eastern Australian land mollusc fauna. Pp. 178-188. In Solen, A. & Bruggen, A.C. van (eds) Biogeographical studies on non-marine Mollusca. (E.J. Brill/Dr W. Backhuys: Leiden).

SOARES, B.M. & THOMÉ, J.W. 2002. Variabilidade morfológica de *Phyllocaulis variegatus* (Molusca, Gastropoda, Veronicellidae) no Rio Grande do Sul, Brasil. Biociências 10(1): 149-168.

TAPPERONI-CANEFRI, C. 1889. Viaggio di Leonardo Fea in Birmania e regiono vicine. XVIII. Molluschi terrestri e d' acqua dolce. Annali del Museo civico do Storia Naturale di Genova 7: 295-359.

TEMPLETON, R. 1858. On a new species of Vaginula from Ceylon. The Annals and Magazine of Natural History I: 49-50.

THE TIMES ATLAS OF THE WORLD 1994. (Times Brooks: London).

THEOBALD, W. 1864. Notes on variation of some Indian and Burmen Helicidae with na attempt at their re-arrangement together with description of new Brumese Gasteropoda. Journal of the Asiatic Society of Bengal 33: 238-250.

THOMÉ, J.W. 1971. Redescrição dos tipos de Veronicellidae (Mollusca, Gastropoda) Neotropicais: VII. Espécies depositadas no " Muséum National d' Histoire Naturelle", Paris, França. Iheringia (40): 27-52.

1975a. Estado atual da sistemática dos Veronicellidae Americanos. Arquivos do Museu Nacional 55: 155-165.

1975b. Os gêneros da família Veronicellidae nas Américas (Mollusca; Gastropoda). Iheringia (48): 3-56.

1983. Veronicellidae (Mollusca, Gastropoda) pantropicais: Primeira ocorrência na Ilhas Christmas (Austrália) do Oceano Pacífico. Iheringia (63):11-25.

1984. Veronicellidae (Mollusca, Gastropoda) pantropicais: III. Redescrição de 5 espécies, com base no exame de tipos depositados no "Naturhistoriska Rikmuseet", de Estocolmo, Suécia. Iheringia (64): 29-46.

1988a. Recaracterização de *Veronicella sloanei* (Cuvier, 1817) (Mollusca, Gastropoda, Veronicellidae). Iheringia (67): 13-35.

1988b. Veronicellidae (Mollusca; Gastropoda) Neotropicais. IV. Redescrição dos tipos de *Vaginula andreana*, *Vaginula reinhardti* e *Vaginula trilineata*, no Zoologisk Museum de Copenhague, Dinamarca. Revista Brasileira de Zoologia 5(1): 61-74.

1988c. Lista das Veronicellidae (Mollusca; Gastropoda) da Jamaica. Revista Brasileira de Biologia 48(4): 807-810.

1989. Annotated and illustrated preliminary list of the Veronicellidae (Mollusca: Gastropoda) of the Antilles, and Central and North America. Journal of Medical and Applied Malacology 1: 11-28.

1992. Veronicellidae (Mollusca; Gastropoda) pantropicais: II. Redescrição de cinco espécies com base em tipos e recaracterização de três espécies de *Semperula* Grimpe & Hoffmann, 1924. Iheringia (73): 91-112.

1993a. Erneute Beschreibung von Veronicella cubensis (Pfeiffer 1840) (Gastropoda: Veronicellide). Archiv für Molluskenkunde 122: 113-121.

1993b. Estado atual da sistemática dos Veronicellidae (Mollusca; Gastropoda) americanos, com comentários sobre sua importância econômica, ambiental e na saúde. Biociências 1(1): 61-75.

THOMÉ, J.W., BRITES, A.B. & BONETTI-OLIVEIRA, V.C.B. de 1994. Nova espécie de *Semperula* Grimpe & Hoffmann para a Tailândia (Gastropoda, Veronicellidae). Revista Brasileira de Zoologia 11(4): 597-604.

THOMÉ, J.W. & LOPES, V.L.P. 1973. Aulas práticas de Zoologia 1. Dissecação de um gastrópode desrovido de concha. Iheringia (3): 34-45.

THOMÉ, J.W., GOMES, S.R. & SILVA, R.S. 2001. Illustrierte und kommentierte Liste der Veronicellidae von Peru (Mollusca: Gastropoda). Archiv für Molluskenkunde 129(1/2): 69-75.

THOMÉ, J.W., SANTOS, P.H. dos & PEDOTT, D.L. 1997. Annotated list of Veronicellidae from the collections of Academy of Natural Sciences of Philadelphia and National Museum of Natural History, Smithsonian Institution, Washington, DC, USA (Mollusca: Gastropoda: Soleolifera). Proceedings of the Biological Society of Washington 110(4): 520-536.

WESTERLUND, C.A. 1883. Von der Veja-Expedition in Asien gesammelte Binnenmollusken. Nachrichtsblatt der deutschen Malakozoologischen Gesellschaft 15(3/4): 48-59.

SOUTHERLY RANGE EXTENSION FOR THE AMETHYSTINE PYTHON *MORELIA KINGHORNI* (SQUAMATA: BOIDAE) IN QUEENSLAND. *Memoirs of the Queensland Museum 49(2): 602. 2004:-* The Queensland endemic Amethystine Python, *Morelia kinghorni* (Harvey, et al., 2000), occurs along the east coast, north of Townsville (Cogger, 2000; Wilson & Swan, 2003). It is largely confined to rainforests and their margins, and other closed forest habitats, but is occasionally found in eucalypt dominated forests and woodlands (Wilson & Swan, 2003). The Environmental Protection Agency's fauna database 'WildNet' contains a record from the Alligator Creek area (19°23'24" S, 146°56'49"E) and a site further south on the upper reaches of Saltwater Creek in Clemant State Forest (19°6'31" S, 146°24'56"E) (EPA, 2003). Specimen records held by the Queensland Museum indicate that the species is found north of Alligator Creek 19°15'59"S, 146°48'59"E (Western Australian Museum, 2003). The Queensland Museum also holds an old record collected around Nebo (21°41'00"S, 148°41'59"E). This record is based on an incomplete skin that was destroyed in 1948 (Andrew Amey, Queensland Museum, pers. comm.). No records have been received for south of Townsville since that time which suggests that the species has either become locally extinct or that the Nebo animal was an escapee rather than being native to the area.

In May 2002, a systematic fauna survey was conducted at Conway State Forest. Vertebrate fauna were surveyed using a combination of Elliott and pit fall traps, harp traps, spot-lighting, active searching and bird censuses over a period of 10 days. A total of 134 species were recorded during the survey including a sighting of the *M. kinghorni*. The snake was observed crossing the old logging road close to the Brandy Creek entrance (20°20'19"S, 148°41'24"E). The area was dominated by tall notophyll rainforest species including *Argyrodendron actinophyllum* subsp. *diversifolium*, *Trema orientalis*, *Melicope bonwickii*, *Cryptocarya bidwillii*, *Endiandra muelleri*, *Terminalia sericocarpa*, *Cryptocarya hypospodia* and *Alstonia scholaris*. The species was readily distinguished from other pythons found in the Conway area by the presence of large, regular scales on the top of its head. This Conway record is significant in that it not only confirms local anecdotal reports regarding the species presence in the area but it also extends the southern limit of the species accepted range by 300km. Since the survey there have been several *M. kinghorni* sightings from the Conway area (20°20'30"S, 148°42'06"E, 4 March 2004, B. Nolan; 20°17'29"S, 148°42'30"E, 9 January 2004, B. Nolan; 20°17'31"S, 148°41'28"E, 21 May 2003, B. Nolan; 20°17'16"S, 148°41'25"E, 17 January 2004, B. Crossman; 20°17'12"S, 148°43'30"E, 8 December 2003, B. Crossman; 20°20'25"S, 148°41'06"E, 23 November 2003, B. Crossman; 20°16'51"S, 148°42'06"E, 13 October 2003, B. Crossman; 20°17'31"S, 148°41'28"E, 24 October 2003, B. Crossman; 20°16'51"S, 148°42'06"E, 26 October 2003, B. Crossman) (Barry Nolan, Queensland Parks and Wildlife Service, pers comm.).

The discovery of *M. kinghorni* in the Conway ranges is an example of how the fauna in the region are influenced by elements of both the Wet tropics and the Central Queensland Coast Bioregions. For at least twelve species, the Conway Range area represents or is close to the limit of their geographical range. Species that are close to their northern limit and are more typically associated with the Central Queensland Coast Bioregion include *Litoria chloris*, *Saproscincus hannahae*, *Lampropholis adonis*, *Phyllurus ossa* and *Eulamprus amplus*. Species which are known from the wet tropics or which are close to their southern limit include *Litoria infrafrenata*, *Megapodius reinwardt* (orange-footed scrubfowl), *Ducula bicolor* (pied imperial-pigeon), *Alcedo pusilla* (little kingfisher), *Tanysiptera sylvia* (buff-breasted paradise-kingfisher), *Aplonis metallica* (metallic starling) and *M. kinghorni*. The presence of *M. kinghorni* and other typically Torresian fauna is also further evidence of an ancient rainforested past extending down along the Queensland coast (Holmes, 1986, Shodde & Tidemann, 1997).

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Literature Cited

COGGER, H.G. 2000. Reptiles and amphibians of Australia 6th ed. (Reed New Holland: Sydney).

ENVIRONMENTAL PROTECTION AGENCY. 2003. WildNet (Database). Environmental Protection Agency. Brisbane. 19 September 2003.

HARVEY, M.B., BARKER, D.G., AMMERMAN, L.K. & CHIPPINDALE, P.T. 2000. Systematics of pythons of the *Morelia amethistina* complex (Serpentes: Boidae) with the description of three new species. Herpetological Monographs 14: 139-185.

HOLMES, D. 1986. Queensland a geographical interpretation. (Boolarong Publications: Brisbane)

SHODDE, R.S. & TIDEMANN, S.C. (eds) 1997. Reader's Digest complete book of Australian birds. (Reader's Digest: Surrey Hills).

WESTERN AUSTRALIAN MUSEUM. 2003. FaunaBase (Database). Western Australian Museum, Perth.

WILSON, S. & SWAN G. 2003. A complete guide to reptiles of Australia. (Reed New Holland: Sydney).

John Augusteyn, Queensland Parks and Wildlife Service PO Box 3130 Rockhampton Shopping Fair 4701, Australia, 3 February 2003.

KAIMON (HETEROPTERA: SCHIZOPTERIDAE), A NEW, SPECIOSE GENUS FROM AUSTRALIA

LIONEL HILL

Hill, L. 2004 06 30: *Kaimon* (Heteroptera: Schizopteridae), a new, speciose genus from Australia. *Memoirs of the Queensland Museum* 49(2): 603-647. Brisbane. ISSN 0079-8835.

The new genus *Kaimon* is described for 27 new species from Queensland, New South Wales and the Northern Territory. The following new species are described: *Kaimon epicarsius* sp. nov. (type species), *K. melanoriensis* sp. nov., *K. thorntonensis* sp. nov., *K. macdowallensis* sp. nov., *K. carbinensis* sp. nov., *K. sidereoriensis* sp. nov., *K. baroalbaensis* sp. nov., *K. finniganensis* sp. nov., *K. polysperes* sp. nov., *K. lambensis* sp. nov., *K. ancylonesioticus* sp. nov., *K. allonesioticus* sp. nov., *K. conwayensis* sp. nov., *K. micropterus* sp. nov., *K. webbensis* sp. nov., *K. pismaensis* sp. nov., *K. athertonensis* sp. nov., *K. allomelanoriensis* sp. nov., *K. leeiensis* sp. nov., *K. eungellanus* sp. nov., *K. kroombitensis* sp. nov., *K. alleungellanus* sp. nov., *K. notipolysperes* sp. nov., *K. byfieldensis* sp. nov., *K. plistonotius* sp. nov., *K. mesambrinus* sp. nov. and *K. bulburinensis* sp. nov.. The new species are figured and a key to submacropterous males provided. The new Australian species are associated with wet forest tracts at 0-1200m elevation along the eastern seaboard of the continent from Iron Range to Barrington House (12-32°S) and one species occurs in the Northern Territory. The presence of undescribed species in Indonesia and the Solomon Islands is noted. The relationship of the new genus with *Pachyplagia* Gross, *Ogeria* Distant and two undescribed genera from Fiji is outlined. The endemism, sympatry and diversity of species is summarised to reveal a few widespread macropterous species and many restricted submacropterous species. ❑ *Hemiptera, Schizopteridae, Ogeriinae, Kaimon, taxonomy, new genus, Australia, rainforest endemism.*

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Collections by the Queensland Museum and the Australian National Insect Collection in wet forest habitats of Australia, particularly coastal Queensland, since the 1970s yielded many specimens of Schizopteridae and Ceratocombidae. The largest generic set of specimens represents a speciose new genus allied to *Ogeria* Distant and *Pachyplagia* Gross. The generic description below is written in comparison to those genera (Hill, 1990a, 1990b). Only Australian species are described below (27 species) but two specimens from Sulawesi and the Solomon Islands are noted. *Ogeria* occurs in mainland Australia (13 species) with a similar range to the new genus and on the islands of Seychelles and Samoa. *Pachyplagia* occurs in eastern mainland Australia (7 species), Sulawesi (Hill, 1990a) and China (Ren, 1991). A cursory examination of 17 samples of Schizopteridae collected by Queensland Museum in Fiji suggests that *Ogeria* and two undescribed ogeriine genera occur there. Notes comparing these with Australian Ogeriinae are given in the discussion but a tabular comparison of their characters as in Table 1 for Australian Ogeriinae awaits further study.

The new genus and *Ogeria* are the smallest Australian Schizopteridae, some being less than a millimeter long. The micropterous females of the new genus have a distinctive, rotund, nymphal habitus but are heavily sclerotised. The males resemble small *Ogeria* but lack a pronotal collar.

The new species are difficult to describe using only drawing and light microscopy. They lack conspicuous diagnostic variation such as the inflated costal lobes of *Ogeria* and accessory male genitalia such as the anophoric appendage of *Pachyplagia*. The diagnostic but minute and complexly contoured paramercs and aedeagus are difficult to slide-mount and illustrate in a standard aspect. The subtle but diagnostic contour variations around the male vertex organ and adjacent pronotal disc are difficult to describe unambiguously in words and would reward scanning electron micrography.

METHODS

Methods are those of Hill (1992) but lack scanning electron microscopy. Some specimens were divided into several mounts after dissection, for example head and thorax residue in ethanol vial and abdomen, wings and legs on one to three

slides. Drawings of small slide-mounted structures such vesiea and leg apiees were done mostly by freehand. Larger body parts were drawn using a gratieule eyepiece and squared paper.

TERMINOLOGY. Terminology mostly follows previous papers by Hill (1990a, 1990b, 1992) which drew mostly upon Emsley (1969) but followed Štys (1969, 1974) for labrum, epipharygeal projection (the labrum of Schuh & Slater, 1995) and pretarsi. The arolium of Štys is the empodial vesicle of Emsley and the pulvilli of Štys are the auxillae of Emsley. However, the pulvilli are now regarded as parempodia as in Štys in Schuh and Slater (1995). Maerosetae are conspieuously long and/or thick setae and qualified as stout if they are thiek. Setae on appendages display a continuous spectrum of lengths and diameters but a few diagnostic distinctions are used for the largest setae on the hind tibiae.

Emsley (1969: 29) said '*Ogeria* and *Pachyplagia* are exeeptional in their dorsally heavily selerotised and papillate abdomen'. The new genus shares this type of abdomen but the term carinulate (provided with small carinae) is used here beeause the tergal seulpture is heavily sclerotised and the 'papillae' coalesce into ridges. The term granulate is used where earinulae fragment such as on the first abdominal tergum of some species.

Esaki & Miyamoto (1959) used tetramerous fore and mid tarsi in males as a subfamily charaeter when establishing the Hypselosomatinae. Emsley used the term pscudotetramerous because sueh tarsi are are not truly tetramerous. He said (p. 19) they oecur 'only in *Hypselosoma* and *Silhouettannus*' and figured the latter, a Sehizopterinae. He also said in his definition of the Hypselosomatinae (p. 83) that they oeeur 'in several other non hypselosomatine genera'. Štys (1982) used the term humpbaeked for similar swollen, telescoped tarsi when establishing the eeratoeombid genus *Kvamula* Štys. The trimerous, telescoped, inerassate tarsi (male fore- and mid legs) of the new genus *Kaimon*, *Hypselosoma* Wygodzinsky, *Pateena* Hill and *Kvamula* appear similar and the term inerassate is adopted here in preference to pseudotetramerous.

Colour notes are not definitive. Colour is subtle and cannot be determined accurately in ethanol preserved specimens and cannot always be retrieved by drying especially if speeimens are stained by label dye.

Monteith (1997) and Yeates et al. (2002) are followed for regional terminology.

ABBREVIATIONS. DAE= distance aeross eyes; DBE= distance between eyes; HE= height of eyes in lateral view; HH= height of head in lateral view; L= labial segment; LFT= length of fore tibia, LHT= length of hind tibia; LA3 and LA4= length of antennomeres 3 and 4; LB= length of body exeluding wings in lateral view; S= abdominal sternum; T= abdominal tergum; LP= left parmere; RP= right paramere; B= berlesate; D= dry; FIT= flight intereept (trough) trap; L= litter; m= moss; OF= open forest; PT= pitfall trap; PK= pyrethrum knoekdown; RF= rainforest; SL= sieved litter; mae.= macropterous (male), sub.= submacropterous (male); NQ= northern Queensland, CQ= central Queensland, SQ= southern Queensland.

The following frequently listed colleetors are listed by surname only: A. Calder; D. Cook; V.T. Davies; J. Gallon; H. Janetzki; G.B. Monteith; S. & J. Peek; G.I. Thompson; T. Weir, D.K. Yeates. Other abbreviations are: MYT for Monteith, Yeates & Thompson; MY for Monteith & Yeates; MT for Monteith & Thompson ; MT/ANZSES for ANZSES team led by Monteith & Thompson; ANZSES for ANZSES team; EQM for Earthwatch team led by Queensland Museum staff.

DEPOSITORIES. Queensland Museum (QM), Australian National Insect Collection (ANIC) .

Order HETEROPTERA
Family SCHIZOPTERIDAE
Subfamily OGERIINAE
Kaimon gen. nov.
(Figs 1-19, Tables 1-4)

TYPE SPECIES. *K. epicarsius* sp. nov.

ETYMOLOGY. *Kaimon*, male noun, from my son's middle name which is a phonetic version of the Greek genitive noun *chimon*, winter.

DISTRIBUTION. Australia (Table 4), Indonesia, Solomon Islands.

DIAGNOSIS. Fitting the definition of the Ogeriinae (Emsley, 1969) with a 4-segmented labium and 3 pairs of abdominal spiraeles but with 4, not 5, veins emanating from trapezoidal eell of the fore wing and a globular to oblong but not elongate, spermatheca. Small, rotund, robust, 0.7-1.2mm long, lacking a pronotal collar, with tarsi 3,3,3 in male and 2,2,3 in female, with incrassate male fore and mid tarsi, with carinulate

abdominal dorsum in males of all pteromorphs but unsculptured dorsum in micropterous, female nymphs. (Table 1)

DESCRIPTION. *Colour.* Light yellowish brown to dark reddish brown, head and disc occasionally with pale patches, appendages yellow-brown to brown, forewings sometimes with cream basal cells that form a pale transverse band across the body when the wings are in repose, micropterous wing pads of females cream or brown, eyes red.

Size and Shape. Males commonly submacropterous but macropters occur in 6 species (4 described here), roughly 0.9-1mm long respectively (Table 2), rotund, 0.5mm wide, male of 1 species micropterous; broadly oval in dorsal view; head declivent; pronotum of macopters steeply inclined; pronotum of submacropters weakly inclined and with specifically diagnostic, complex contours, often decurved anteriorly, occasionally overhanging vertex; pronotal collar absent; abdominal dorsum highly convex, with longitudinal carinate microsculpture. Females micropterous, with rotund, nymphoid habitus, 0.93 (0.76-1.04)mm long, 0.5mm wide; dorsum convex in lateral view; pronotum not inclined, without complex contours; abdominal terga smooth, not carinulate.

Dimensions. (Table 2). Relationships between dimensions for submacropterous males are, with ranges in parentheses when known: DBE = 53% DAE (48-63%); HE = 44% HH (35-53%); HE = 33% DAE (27-38%); LA3 = 76% LA4 (68-86%); LA3+LA4 = 58% LB; LFT = 64% LHT (59-74%); LHT = 48% LB; LHT = 89% WP; LP = 56% WP (49-71%); LB = 192% WP (170-230%) and DAE = 84% WP. Pronotum relatively longer and more variably so in submacropterous males than females, that is, for females LP = 43% WP (38-46%). LP greatest in macropterous males and least in females. Pronotum wider in macropterous males than females and submacropterous males. LB (submacropterous male) = 97% LB (female), range 91-104% (Table 3). LHT, LFT, LA3, LA4, DBE do not vary between pteromorphs or sexes.

Head. Head short in lateral view, curvature of frons less convex in posterodorsal view than in *Ogeria*, weakly to strongly flattened in lateral view in some species (Fig. 6E,F); not as tall in anterior view as *Pachyplagia*; areas laterally to labrum squarely inflated like *Ogeria* but excavated to accommodate antennal bases; genae without long, procurved setae (unlike *Pachyplagia*); lateral frons with 2 pairs long setae, longer pair recurved, shorter pair procurved, inserted above antennal bases on pair of faint ridges (Fig. 2A-C) which perhaps indicate path of frontal suture and which run parallel to and ventrally to frontal cibarial muscle scars; central frons with about 3 pairs of inconspicuous, incurved setae medially (*Ogeria* has 3 conspicuous pairs, *Pachyplagia* none); cibarial muscle scars of vertex apparently fine punctures; 4 arcs of cibarial muscle scars on vertex and frons more or less merge to form 2 larger arcs (left and right) in an X-shape; vertex with 1 lateral pair of parocular macrosetae curving over the eyes; male vertex usually with conspicuous pit or U-shaped groove and lobe, specifically diagnostic in detail but vestigial in some species (Figs 2A-D, 3-9); ocelli present only in macropters, located 1 ocellar-diameter from eyes and 2 diameters ventrally to the parocular macrosetae (Fig. 2A-D); eyes large, coarsely faceted, medial margins more or less parallel in dorsal view; labrum oblong, base semicircular, apex square, with 5 macrosetae (1 proximal and 1 distal pairs of long procurved macrosetae plus single, central very long procurved macroseta); labium 4-segmented (Fig. 10K), reaching posterior margin of fore coxae; epipharyngeal projection reaching apex of L2 (Fig. 10A); bucculae inconspicuous (as in allied genera), open posteriorly, confluent with medial extensions of proepisternal rims, forming labial cradle (Fig. 10B,C); antennae reaching mid abdomen, A3 curved, A4 straight.

Prothorax. Pronotum weakly convex, fine punctures of disc (perhaps stellate microtubercles) restricted to posterior quarter (coarse and on whole disc in *Ogeria*), collar absent; pronotal contours often specifically diagnostic in submacropterous males (Figs 3-9); pronotum not separable from head by dissection, suture bearing internal phragma widening laterally of vertex pit when latter present (Fig. 10B,C); posterior margin strongly and sinuously convex in macropters, weakly and sinuously convex, straight or rarely concave in submacropters and micropters; lateral margins in dorsal view weakly sinuate and convergent in macropterous males, sinuate and convergent or parallel in submacropterous males, weakly convex and convergent in females; lateral margins tumid or not in males, that is, in sectional view there is an inflexion of both the disc and the propleurae near the margin (Fig. 2B,C) or only the disc (compare Fig. 2A).

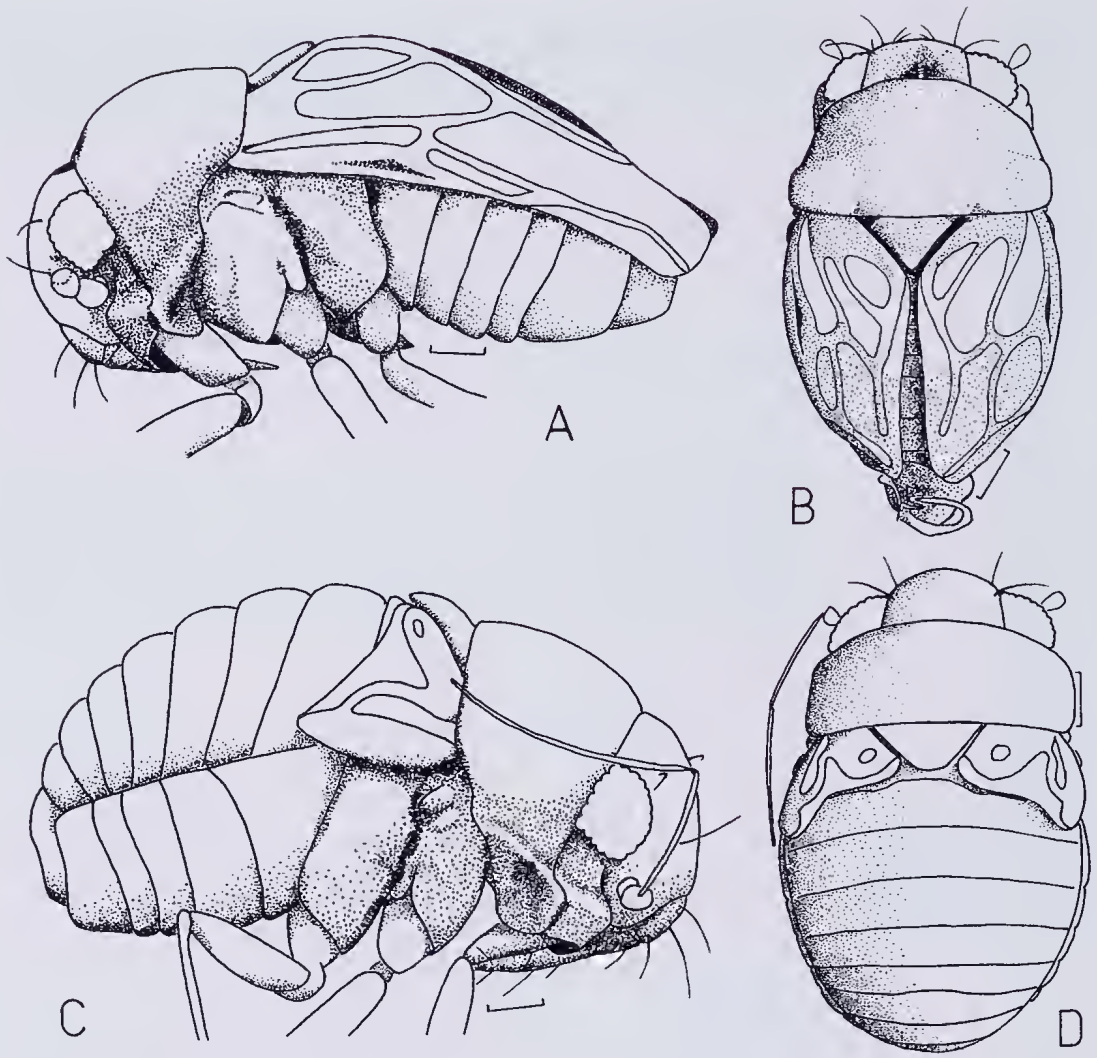

FIG. 1. Submacropterous ♂ and micropterous ♀ habitus. A, ♂ *K. allomelanoriensis*, lateral; B, ♂ *K. melanoriensis*, dorsal; C, ♀ *K. allomelanoriensis*, lateral; D, same, dorsal. Scale lines 0.1mm.

Propleurae short, inflated; proepisternum and proepimeron of equal vertical length; propleurae shorter vertically and more broadly inflexed in ventral portion in females than in males; propleurae forming well-defined shelves supporting antennal bases (as in *Ogeria* and to a lesser extent, *Pachyplagia*), proepisternum forming most of shelf, proepimeral portion of shelf tapering posteriorly in most species but in a few species widening (in dorsal view) to rectangular (Fig. 4B-D) or acute angle (Fig. 14O) (including females of some species, at least); medial extensions of proepisternal rims and bucculae embracing base of labium; rims and bucculae lacking opposing tubercles. Prosternum steeply inclined.

Pterothorax: (Fig. 11) Apex of scutellum, in lateral view, not projecting posterodorsally (unlike *Pachyplagia*); triangular, not reaching posterior margin of metanotum in males; rounded, reaching posterior margin of condensed metanotum in females; scutellum with large deep lateral pits near intersegmental junction in males, smaller pits in females. Metanotum of males well

TABLE 1. Comparison of *Kaimon, Pachyplagia* and *Ogeria*. Dimensions in millimeters. 1, spines probably homologous with branches as they lengthen; 2, hooded in one undescribed Fijian ogeriine genus.

Character	*Pachyplagia*	*Ogeria*	*Kaimon*
Length overall	1.3-1.4	0.8-1.2	0.8-1.2
Ratio LHT/LB	0.54	0.42	0.48
Ratio LFT/LHT	0.60-0.72	0.60-0.72	0.59-0.74
Ratio HE/HH	0.25	0.26-0.38	0.35-0.53
Ratio HE/DBE	0.33	0.17-0.24	0.47-0.53
Ratio DAE/DBE	1.30-1.40	1.48-1.77	1.60-2.10
Ratio LA3/LA4	1.15-1.40	0.91-1.04	0.68-0.86
Frons cibarial muscle scars	discrete from vertex group	not evident	concurvilinear with vertex group
Form vertex cibarial scars	deep furrow ×2	4 coarse pits ×2	several fine pits ×2
Male vertex pit	absent	absent	present
Pronotal collar	present	present	absent
Male fore and mid tarsi	slender	slender	incrassate
Male tarsal formula	2,2,3	3,3,3	3,3,3
Female tarsal formula	2,2,3	3,3,3	2,2,3
Macropterous males	yes	yes	yes
Submacropterous males	no	yes	yes
Brachypterous males	no	yes	yes
Micropterous males	no	no	yes
Macropterous females	yes	yes	no
Submacropterous females	yes	yes	no
Brachypterous females	no	yes	no
Micropterous females	no	yes	yes
Mesosternal keel	small	medium	large
Contouring of S2/3 to coxae	moderate	strong	stronger
Thorax/abdomen articulation	ball and socket	none	ridge and groove
S2/S3 articulation	ball and socket	ball and socket	none (connate)
Posterior margin genital capsule	convex	convex	emarginate
Gen. cap. aperture constriction	at <0.5 from anterior	at midlength	at >0.5 from anterior
Vesical loops	one or more	one or less	one or less or sinuous
vesical spines/dentition	absent-basal singular	absent-elaborate	absent-subapical minor
Vesical branch length [1]	absent	absent or short	absent, short or long
Carinulation of male dorsum	T1 - T6	T1 - T8	T1 - T7
Length of carinulae on T3-6	half tergum	full tergum	third to half tergum
Left paramere form	short, oblong	short, oblong	long, slender
Left paramere basal digit	present	present	absent
Right paramere form	long, slender	short, tapering	very short, trilobate
Size of parameres	L<R	L=R	L>R
Anophore form	tubular	dorsally tubular	completely ringlike
Anophoric appendage	present	absent	absent
Anal aperture from T9 margin	0.3-0.5 diameters in	0 diameters in	2-3 diameters in
Profile female anus [2]	flush with T9	flush with T9	raised, not hooded
Gonagulum struts	asymmetrical	absent	absent
Anterior gonapophyses	asymmetrical	symmetrical	symmetrical
Posterior gonapophyses	fused, transverse plate	discrete, sclerotised	?transverse membrane
Spermatheca	oblong	absent	Globular-short oblong

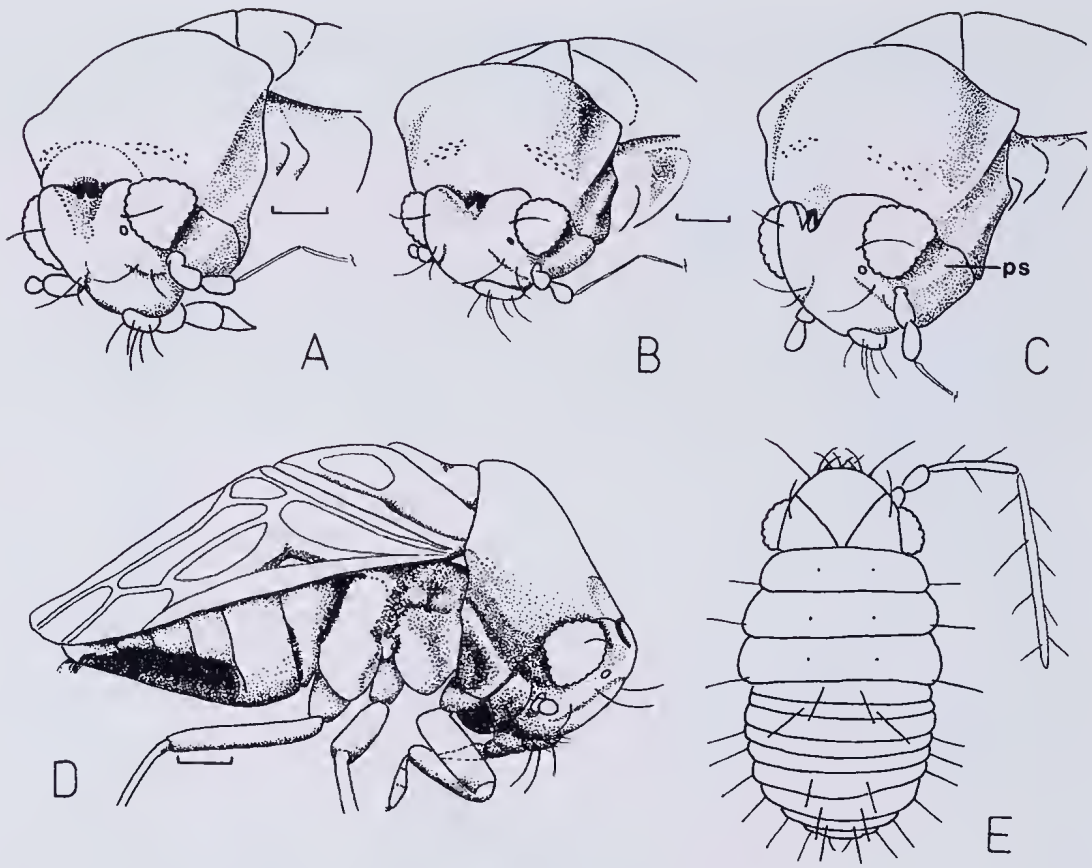

FIG. 2. A-D macropterous ♂♂. A, *K. epicarsius*; B, *K. sidereoriensis*; C, *K. polysperes*; D, *K, notipolysperes*; E, early instar nymph *K. notipolysperes*. Scale lines 0.1mm. ps=propleural shelf.

developed, bearing faint longitudinal carinulae; metanotum of females condensed; lamina projecting from posterior margin of metanotum narrow, with convex margin, largest in macropters, absent in females.

Mesopleurae with 2 tumescences near dorsal ends level with propleural and metapleural shelves. Metepisternae large and inflated, dorsal ends forming shelves probably supporting A4 and forewings in repose, shelf smaller in (micropterous) females; metapleurae not articulating with abdomen by ball and socket system (see Hill, 1990a) but tumid posterior margins of metepisternae weakly slotting into raised groove on S2/3 formed by parallel sublateral carinae (Fig. 14N); metepimera small, of males with slight protuberance at dorsal end of posterior margin complementing truncate anterolateral angles of abdominal S2+3.

Lateral parts of mesosternum steeply inclined, forming posterior walls of midcoxal cavities, delineated laterally from metepisternae by vertical carina extending ventral to and colinear with groove separating meso- and metapleurae. Mesosternal keel large, interlocking anteriorly with posterior notch of prosternum, oblique ventral edge colinear with metasternal keel in profile; metasternal keel not embraced by medial ends of transverse carinae that border anterior margins of mid coxal cavities unlike *Pachyplagia* and *Ogeria* (Hill, 1990 erroneously described these carinae as posterior to midcoxal cavities in *Ogeria* although posterior carinae do also occur in that genus), posteroventral angle produced acutely, embraced by hind coxal spicule pads; metendosternite slender, apically bilobed.

Legs. (Fig. 12) male tarsi 3,3,3, female 2,2,3, not elongate, male fore- and midtarsi incrassate (unlike *Ogeria* and *Pachyplagia*) and with membranous, inflatible arolium; all legs both

sexes with pairs of setiform parempodia as long as claws; fore tibiae enlarged apically, with 3-4 stout, apical macrosetae and anteroventral comb of 5 setae; mid tibiae with 4 stout, apical macrosetae and posterior comb of 5 setae; hind tibia with 1 stout, posteroventral macroseta located 0.71-0.84 from base of tibia and 1.1-2.9 tibial-diameters long, 1 anterior macrosetae located 0-1.3 tibial-diameters proximally of posteroventral and 0.6-0.9 tibial diameters in length, sometimes two finer posteroventral macrosetae <1 tibial diameter in length near stout, posterovental macroseta, 3 stout, apical macrosetae, ventral row of around 8 erect, fine setae of almost tibial diameter in length; fore and mid tibiae subequal; LFT/LHT 0.65 (0.58-0.74) for all pteromorphs. Nymph 2, 2, 2, with setiform parempodia.

Wings. (Fig. 13) Fore wings of females always micropterous, of males usually submacropterous but also macropterous in some species (pterygodimorphic) or rarely mieropterous; micropterous wings moulded to contours of meso- and metanota, reaching posterior margin of T2 (females) or T4 (males); submacropterous fore wings reaching abdominal apex; macropterous forc wings extending beyond abdominal apex, adding 15% to length ovcrall; male forewings with short, ventral carina along posterior margin of costal cell near base ofm junction complementing mesepimeral contours; macropterous costal lobe sclerotised but not inflated, uniform from species to species, 4 veins emanating from trapezoidal cell (Fig. 13A), 2 veins reaching apical margin (1 or 2 in submacropters, Fig. 13E-F), vannal vein (lettered 3 in Fig. 13E) almost reaching wing apex, representing third free vein but sometimes anastomosing with preceding vein; wing coupling (Fig. 13C) adjacent to 2V, (like Emsley, 1969, fig. 65). Hind wings large and quadrilobate in macropters, 3 veins, slender jugal lobe; hind wings absent in other pteromorphs.

Abdomen. Abdominal dorsum and venter strong and rigid, separated by narrow, lateral membranes. Abdomen without sockets for articulation with thorax but with paired sublateral carinae on S2+3 embracing posterior margins of metepisternae (Fig. 14N). Venter hemicylindrical. Dorsum morc arched than venter, not sexually dimorphic in general contours but carinulate if covered by forewings (males) (carinulae present but diminished in micropterous male), not carinulate if exposed (females). T8 discrete from T1-7 in males.

Male dorsum (Figs 14A-C, 15A-C) T1-7 fused into rigid dorsal plate, more or less equally convex; intersegmental sulci reaching lateral margins of plate; T1 narrow, T1-2 more fused than T2-7 with sulcus merely a sinuous depression; male T2-7 each with 12-16 parallel, longitudinal carinulae occupying anterior two-thirds or more of each segment (but only one-third in mieropterous male of *K. micropterus*) and linked posteriorly on each tergum by raised, smooth, transverse band that widens laterally; carinulae often sinuate, bent or incomplete and not strictly colinear from segment to segment; incomplete submedial carinulae appear as dots or short dashes on T3-5 in same irregular pattern in many species (Fig. 15B), no narrow transverse carina additional to the transverse bands on T3-6 (unlike *Ogeria*); carinulae of T1 distinct (Fig. 15A), reduced to illdefined triangles or merely granular (Fig. 15B); anterior and posterior margins of T2-7 not decurved except anterior margin T7 but T2-7 each with transverse gutter at one-third from anterior margin; adjoining margins T6 and T7 not decurved but possibly flexible; postcrolateral angles T7 roundly produced posteriorly a little, T7 twice as broad as preceding terga, granulate or not in posterior half (granulate in *K. sidereoriensis*, not in *K. pismaensis*); lateral margins T1-7 narrowly deflexed to form smooth rim parallel to sternal margins and separated from them by a narrow membrane; adjoining margins T7 and T8 not intimately connected; T8 asymmetric, with high, transverse carina near anterior margin delimiting smooth, inclined posterior area, 2 oblique carinae branching from the submarginal anterior carina subdivide posterior area; no discrete laterotergites but T8 deflexed at both ends as vertical struts lying internally to S7, spiracles near deflections, apices of struts connecting to S8 membranously and asymmetrically.

Female dorsum (Figs 1D, 15E) T1-8 fused into rigid dorsal plate; T1-8 not carinulate, relatively uniform and equally convex but T1 very narrow; T1-2 not more fused than T2-8 but sulcus sinuate; sulcus between T7 and T8 procurved to S6-7 sulcus; intersegmental sulci of T1-6 stop before reaching lateral margins of dorsal plate; lateral margins T1-8 narrowly deflexed to form smooth rim parallel to lateral margins of venter and separated from them by a narrow membrane anterior margins of T2-8 weakly decurved, posterior margins not; T2-8 each with around 16

submarginal, anterior tubercles; T8 not depressed posteriorly; no discrete laterotergites.

Venter S2 and S3 partly fused (Fig. 14H), line of fusion obscure laterally, no interlocking process and socket laterally; S2 membranous medially and bearing tiny rugose sclerite anteromedially which may be vestige of S1; S3 with small membranous area and larger rugose pad anteromedially; S2+3 steeply inclined forming posterior wall of hind coxal cavity, contours more closely complementing coxae than in *Ogeria*; S3 with pair of conspicuous carinae posterior to coxal impressions and S2 with lesser pair of carinae near lateral ends of S3 carinae together loosely embracing metepisternae (Fig. 14N); S4-7 each with about 26 anterior, submarginal tubercles; posterior margins of male S5 and S6 possibly narrowly, symmmetrically overhanging following sternum in many species but in some an asymmetric ledge projects (Fig. 14F,I) or a digitiform ledge in one undescribed species; discs S5 and S6 asymmetric in some species in conjunction with S7 impression; male S7 large, disc asymmetrically contoured to greater or lesser extent, conforming to retracted genital capsule, frequently impressed left of midline; posterior margin male S7 concave and variably asymmetric, sometimes strongly produced on right posterior margin (southern species); male S8 narrow, reflexed internally above posterior margin of S7 (Fig. 15D), connecting to T8 by asymmetric membranes from midline (to right) and from left side (to left); female S7 slightly larger than preceding sterna; female S8 narrow, reflexed internally above S7 (Figs 15E, 19I).

Spiracles on S6, S7 and T8 sclerites in both sexes.

Male Terminalia. (Figs 15-19) Genital capsule mostly overlapped by S7 in repose, anteriorly reaching S6, half to two-thirds of floor is anterior to anophore and hyaline (Fig. 15I); extreme anterior margin not inflexed but anterolateral margins upcurved; posterior margin in ventral view usually roundly oblique and medially emarginate; left posterior broadly rounded but with small, acute tumescence in some southern species; right posterior angle smaller, bearing indistinct (Fig. 14I), acute (Fig. 14L-M) or spinous tumescence (Fig. 14C,F); faint transverse carinae on left side of dorsal aperture marking line of overlap with T8, no or fainter carina to right of aperture (Figs 17A, 18A). Short, square anophore ring (not as long as *Ogeria* and *Pachyplagia*), without process, lying in constriction of dorsal aperture of capsule, right side with indistinct condyle articulating with capsule. Parameres clearly asymmetric, relatively uniform across species; left paramere (Fig. 19D) with bulbous base, long, curved spinous arm varying twofold in length between species, no basal digit; right paramere small, stout, bi- or trilobate, concave face conforming to aedeagal conjunctive, with basal digit. Basal plate a slender, arc-like, irregular sclerite. Aedeagus similar to *Ogeria* and *Pachyplagia*, 3 conjunctival sclerites forming conjunctiva (which probably includes phallobase of Emsley (1969)) embracing spherical reservoir between basal plate and base of vesica, 1 sclerite with obscure or conspicuous spinous process (Figs 15J, 16I, 18D, 19E); vesica spinous, projecting to right to form tighly recurved loop (Fig. 1B), an incomplete, spiralled loop (Figs 16I, 17G,F) or sinuous path (Figs 16A, 17E); vesica without major dentation but some species (northern Queensland) with single, subequal or longer branch (Figs 15J,K, 16A-F,H, 17A-C,E,F, 18A, 19D) or short, subapical branch (Fig. 19A-C), vesica and/or branch apices simple, bifid or bearing small tooth, some species (southern Queensland) without vesical branch (central Queensland species with or without branch).

Female Terminalia. T9 hinges from near vertical plane in repose to horizontal in extension, with broad, inflexed, hyaline marginal flange internally overlapping S7 in repose; external, submarginal carinae present but gonagulum struts absent; sclerotised anal tube located centrally in roof of T9, aperture remote from posterior margin; extensible membranous anal tube without sclerites; anterior gonapophyses (Fig. 19F-I) in form of a pair of elongate tapering, membranous lobes with longitudinal concavity along inner faces and vestigial, longitudinal, sclerite; posterior gonapophyses obscure and membranous, possibly fused as a tranverse membrane; no asymmetry evident; spermatheca present on left side at level of S6-7 interface (Fig. 15E), globular or bilobate (Fig. 19J-L).

GENERIC MORPHOLOGICAL NOTES. *Male Vertex Organ*. There is a geographic trend to modification and loss of the vertex organ. Broadly, northern species have an open pit, central species have a lobe covering the pit or an evaginated area while southern species have secondarily lost the pit.

Discrimination of species relied heavily upon the vertex and the adjoining area of the pronotal

TABLE 2. Dimensions of males (submacropterous or micropterous) and females of *Kaimon* in millimeters. N, number of specimens measured.

Kaimon	Males						Females					
	LHT	WP	LB	DAE	LB	-	LHT	WP	LP	DAE	LB	1
epicarsius	0.41	0.50	0.27	0.41	0.41	30	0.45	0.53	0.24	0.41	0.97	18
melanoriensis	0.42	0.50	0.25	0.41	0.84	1	1	1	1	-	1	1
thorntonensis	0.44	0.44	0.24	0.44	0.86	7	0.43	0.17	0.20	0.41	0.81	-
macdowallensis	0.41	0.41	-	0.36	0.91	1	1	1	1	1	1	1
carbinensis	0.36	0.41	0.21	0.48	0.78	1	1	1	1	1	-	1
sidereoriensis	0.44	0.42	0.41	0.46	0.76	2	0.35	0.41	0.17	0.39	0.80	18
baroalbaensis	0.45	0.41	0.20	0.35	0.76	1	0.34	0.39	0.15	0.45	0.76	1
finniganensis	0.42	0.44	0.25	0.40	0.80	4	0.44	0.50	0.21	0.42	0.45	4
polysperes	0.17	0.54	0.28	0.42	0.50	30	0.45	0.54	0.28	0.44	0.48	23
lambensis	0.50	0.50	0.28	0.42	0.42	7	1	-	1	1	-	-
ancylonesioticus	0.41	0.42	0.25	0.38	0.84	4	0.41	0.47	0.21	0.41	0.92	4
allonesioticus	0.42	0.45	0.25	0.38	0.91	1	0.42	0.48	0.21	0.42	0.92	1
conwayensis	0.45	0.44	0.28	0.41	0.44	2	0.44	0.50	0.22	0.47	0.50	6
micropterus	0.37	0.41	0.24	0.35	0.82	6	0.43	0.42	0.17	0.45	0.84	5
webbensis	0.36	0.41	0.21	0.44	0.84	1	0.46	0.41	-	0.44	0.81	1
pismaensis	0.41	0.50	0.28	0.40	0.48	2	0.44	0.51	-	0.43	0.50	4
athertonensis	0.42	0.50	0.27	0.42	0.48	5	0.46	0.50	0.21	0.44	1.03	4
allomelanoriensis	0.45	0.45	0.24	0.39	0.91	1	-	-	-	1	-	-
leeiensis	0.42	0.50	0.28	0.40	0.50	1	-	-	1	-	-	
eungellanus	0.50	0.44	0.28	0.38	0.50	1	0.42	0.50	0.22	0.41	0.48	1
alleungellanus	0.50	0.48	0.34	0.41	0.47	2	0.42	0.52	-	0.42	0.50	1
notipolysperes	0.44	0.50	0.27	0.40	0.48	-	0.41	0.50	0.22	0.42	0.50	6
byfieldensis	0.45	0.48	0.31	0.40	0.97	2	0.42	0.53	-	0.42	1.04	1
kroombitensis	0.44	0.48	0.32	0.40	0.97	2	0.42	0.49	0.23	0.40	0.95	6
plistonotius	0.43	0.50	0.25	0.41	0.97	2	0.42	0.51	0.25	0.41	0.94	3
mesambrinus	0.42	0.48	0.25	0.41	0.97	1	0.43	0.53	0.24	0.43	0.99	1
bulburinensis	0.41	0.48	0.28	0.39	0.91	1	0.42	0.50		0.42	0.94	1
Mean	0.42	0.47	0.25	0.39	0.90	-	0.42	0.49	0.21	0.41	0.93	-

disc in submacropterous males. Descriptions of the vertex organ in anterior, lateral and dorsal view are provided for each species but scanning electron micrographs of the same area for all species would have been less ambiguous. In species from NQ, Northern Territory (and Solomon Islands) the male vertex organ is typically a conical invagination of the vertex projecting into the head at its interface with the pronotum. The internal apex may bear an aperture (Fig. 10J,G). A longitudinal carina running along the anterior face partly partitions the pit into right and left chambers. The dorsal end of this carina or partition is visible externally at the aperture of the pit and termed the medial ridge here (Fig. 10I). The ridge is flush with or recessed below the plane of the aperture and merges with the anterior rim of the pit either confluently or disjunctly.

In 6 species from NQ (Fig. 3A-F) the vertex around the pit aperture is impressed so that the aperture lies below the general plane of the vertex. In such cases the anterior edge of the pit is not sharply defined. In other species from NQ the aperture is not depressed and the anterior edge of the pit is sharply defined and flush or occasionally labiate (Figs 3H-L, 4A-G). The lateral margins of the pit are sometimes inclined as they approach the pronotum. The terms inner and outer rims are used to distinguish the lower or inner edges from the upper or outer edges of the rim near where it meets the disc. In the species from the NT the pit is not depressed but the anterior edge is roundly rather than sharply

defined and lies concentrically within a moat-like depression formed by the cibarial muscle scars (Fig. 3G).

In species from CQ and 1 from SQ the aperture is obscured by a lobate protrusion of the vertex from the anterior margin of the pit so that a U-shaped slit is seen in dorsal view of the vertex (Fig. 4H-L). In *K. eungellanus* the internal pit-organ is globular (Fig. 10F-G) whereas in *K. alleungellanus* and *K. notipolysperes* it is conical (Fig. 10H,E). The lobate vertex organ perhaps lacks a carinal partition but possesses a cylindrical crest along its posterior face. This is visible in internal view of the cleared head (Fig. 10E).

In *K. kroombitensis* from CQ the vertex organ is evaginated and separated by a cleft from the vertical anterior lobe. The organ forms a vertical posterior lobe of the vertex that adjoins the overhanging anterior margin of the pronotal disc. The cylindrical crest mentioned above is present internally on the posterior lobe of the vertex.

Three species from CQ and SQ and NSW lack the organ probably as a secondary loss. Vestiges appear in the contours of the vertex and adjacent pronotal disc (Fig. 9).

Perhaps this organ (secretory or sensory) is analogous with others 'sensory areas' (Hill, 1984) that occur on various parts of the male body in locations characteristic of genera, for example the clypeal, labral, fore tibial and sternal (S1) organs in *Hypselosoma*, the recessed pronotal collar complemented by a vertex furrow in *Cryptomannus*, the setigerous pronotal furrow in *Rectilamina*, the setigerous clavus accompanied by a cavity of the adjacent scutellum in *Duonota*, the minute corial apex organ of *Pachyplagioides* and perhaps the costal lobe of *Ogeria*. Such an organ is absent in *Pachyplagia*.

Thorax. Emsley noted that the schizopterid metendosternite, a posterior process of the metasternum, 'projects into the abdomen' but in Australian Schizopteridae it projects almost vertically down, running posterior to the hind coxal bases and lying external to the base of the abdomen. It may restrain the hind coxal bases posteriorly.

The venation of submacropters and micropters is sometimes unstable within individuals in that veins may or may not anastomose distally or distal veins may fail to appear (Fig. 13E,F). Some indication of this is given above in the generic description and below in species descriptions.

TABLE 3. Proportions for species of *Kaimon* as percentages. sm, submacropterous male; f, female.

Kaimon	LBsm/LBf	LP/WP sm	LP/WP f
epicarsius	44	54	44
melanoriensis	-	51	-
thorntonensis	44	55	44
macdowallensis	-	-	-
carbinensis	-	-	-
sidereoriensis	44	56	46
baroalbaensis	100	44	38
finniganensis	44	57	42
polysperes	44	54	44
lambensis	-	58	-
ancylonesioticus	64	60	45
allonesioticus	49	56	44
conwayensis	96	64	45
micropterus	46	49	44
webbensis	100	44	-
pismaensis	92	56	-
athertonensis	65	54	38
allomelanoriensis	-	54	-
leeiensis	-	65	-
eungellanus	100	49	49
alleungellanus	100	71	-
notipolysperes	101	55	44
byfieldensis	44	64	-
kroombitensis	102	67	45
plistonotius	103	50	46
mesambrinus	-	52	45
bulburinensis	97	58	-
Mean	97	57 (49-71)	43 (38-46)

Abdomen. The shape of S7 varies but is not as easily used as in *Ogeria* to diagnose species but would yield useful characters with scanning electron micrography. In all species the right posterior corner is produced posteriorly to a greater (southern species as in Fig. 14G,J) or lesser extent (northern species as in Fig. 14C,F,I). Accompanying this trend is a large depression of the right side of S5-7 discs in southern species. Two northern species have a diagnostic depression adjoining a tumescence on the right side of the S7 disc near its posterior margin (Fig. 14C).

Although the contours of T8 appear to complement the retracted, sinuous vesica in *K. epicarsius* it was not possible to document variations of T8 in other species linked to their uniramous, biramous, looped or non-looped

vesical forms. Variations that were detected appeared to be minor.

Vesica. The path of the gonoduct is difficult to determine. In some species it was unclear whether the longer or shorter ramus of a biramous vesica bore the gonoduct and which to term the vesical branch versus the vesica. In many species the vesica and branch form an incomplete spiralled loop. In *K. epicarsius* and *K. finniganensis* the vesica follows a sinuous tricurvilinear path with two right angled bends in different planes followed by a recurved bend distally. In *K. melanoriensis* the vesica follows a tight U-shaped bend at mid length. In *K. ancylonesioticus* it is apically recurved but in a direction opposite to the curvature of the proximal portion.

Ratios. Various ratios such as DAE/DBE, HE/HH, HE/DAE and LHT/LB were plotted. No outlying species were detected. Similarly, the length and position of the two distal but non apical macrosetae on the hind tibae revealed no outlying species and sufficient variation within species and between left and right of individuals to constrain their use in diagnosis. For example in 4 specimens of *K. sidereoriensis* the position of posteroventral macroseta 0.78-0.84 from the base of the hind tibia, its length 0.107-0.145 of tibial length or 1.5-2.2 of tibial diameter. However the posteroventral macroseta is long (2-3 tibial diameters) in species from SQ and NSW.

GENERIC DISCUSSION. Emsley (1969) defined the Ogcriinae as having 5 veins emanating from the trapezoidal cell, a 4-segmented labium, an elongate spermatheca and 3 pairs of abdominal spiracles. He included *Ogeria*, *Pachyplagia*, *Luachimonannus* Wygodzinsky (1950), *Kokeshia* (Esaki & Miyamoto, 1959) and *Chinannus* (Wygodzinsky, 1948).

In the context of his definitive interpretation of schizopterid venation, Emsley remarked that the venation of all the genera is fully comparable. *Kaimon* has only 2 of those characters (labium and spiracles) but appears closely allied to *Ogeria* in general structure. Although Wygodzinsky's descriptions of *Luachimonannus* and *Chinannus* omit or contradict some of the above definition, Emsley supplied new observations of these taxa to support his classification. However, Hill (1990b) failed to find a spermatheca in *Ogeria* and figured that of *Pachyplagia* (Hill, 1990a) as less elongate than the original drawing (Emsley, 1969) although the dilate duct raises uncertainty in delimiting the spermatheca. Hill also found that 4 or 5 veins emanate from the trapezoidal cell in various species of *Ogeria* and *Pachyplagia* although 5 is more common. *Kaimon* is here placed in the Ogeriinae because of its similarity to *Ogeria*.

The concept of Ogeriinae awaits reconsideration. This will be easier when 2 new genera from Fiji are described. A cursory examination of Schizopteridae collected by Queensland Museum in Fiji revealed 2 undescribed ogeriine genera and *Ogeria*. One genus is slightly larger than Fijian *Ogeria*, has trimerous, slender tarsi in both sexes, no pronotal collar and the anal aperture of females lies immediately inside the submarginal carina of T9 and has a distinctive, hooded profile. The other genus is larger, has trimerous, slender tarsi in both sexes, a pronotal collar and the anal aperture of females lies immediately outside the submarginal carina of T9 and is not hooded. Both undescribed genera appear to have a transverse sclerotised plate, reminiscent of *Pachyplagia*, for posterior gonapophyses. Only submacropterous and brachypterous morphs of both sexes were seen so that the number of veins emanating from the trapezoidal cell cannot be known. Both genera had a four-segmented labium that was incrassate subapically in contrast to *Ogeria*.

KEY TO AUSTRALIAN SPECIES OF *KAIMON* USING NON MACROPTEROUS MALES

1. Vertex simple, SQ and NSW only 2
   Vertex with pit or U slit 4
2. Pronotal disc weakly flattened anteromedially (Fig. 9A-C) . . . . . *plistonotius* sp. nov.
   Pronotal disc clearly flattened anteromedially (Fig. 9D-I) 3
3. Vertex paler medially than laterally *mesambrinus* sp. nov.
   Vertex concolourous . . . . . *bulburinensis* sp. nov.
4. Vertex with U-slit, SQ and CQ, (Fig. 8H-L) 5
   Vertex with pit, NQ, (Figs 7A-L, 8A-G) 9
5. Pronotal disc overhanging vertex (Fig. 6I) *kroombitensis* sp. nov. . . . . .
   Pronotal disc not overhanging vertex. 6
6. Genital capsule with hooked spinous process, pronotal disc undulating, flat, posterior margin rolled (Fig. 6H) . . . . . *eungellanus* sp. nov.
   Genital capsule without hooked process, pronotal disc without three undulations, posterior margin not rolled 7
7. Small flat area anteromedially on pronotal disc, pronotal disc strongly convex anteriorly and with single undulation, weakly sinuous posteriorly in profile (Fig. 6J) . . . . . *alleungellanus* sp. nov.

Large flat or shallowly concave area anteromedially on pronotal disc, pronotal disc less convex and without undulation (Fig. 6K-L) 8

8. Lateral margins of pronotal disc parallel (Fig. 4K), not dilate (Fig. 6K), left paramere 0.131mm long . . . . . *longnotipolysperes* sp. nov.

Lateral margins of pronotal disc convergent (Fig. 4L), dilate (Fig. 6L), left paramere 0.098mm long . . . . . *byfieldensis* sp. nov.

9. Anterior rim of pit depressed, merging anteriorly with broad impression or longitudinal furrow anterior to pit (Fig. 3A-E). 10

Anterior rim of vertex pit sharply defined, sometimes raised, occasionally minutely notched medially, vertex not broadly impressed or longitudinally sulcate anterior to pit (Figs 3F-L, 4A-G) 14

10. Lateral margins of pronotal disc convergent (Fig. 3A,B) 11

Lateral margins of pronotal disc more or less parallel (posterior angles may be tumid) (Fig. 3C-E) 12

11. Vesica sinuous, with angular curves (Fig. 16A-C) . . . . . *epicarsius* sp. nov.

Vesica sector-shaped (Fig. 1B) . . *melanoriensis* sp. nov.

12. Lateral margins pronotal disc not dilate (Fig. 5D,E). . 13

Lateral margins pronotal disc dilate (humeral angle tumid but disc margins otherwise parallel in dorsal view) (Fig. 5C). . . . . *thorntonensis* sp. nov.

13. Pronotal disc flat posteromedially, posterior margin truncate medially, vertex broadly impressed (Figs 3E, 7E). . . . . *carbinensis* sp. nov.

Pronotal disc weakly convex posteromedially, posterior margin smoothly convex, vertex narrowly impressed (Figs 3D, 7D) . . . . . *macdowallensis* sp. nov.

14. Vertex pit lip raised (Figs 5G, 6C, 6G) 15

Vertex pit lip flush (Figs 5H-L, 6A,B,D-F) 17

15. Lateral margins of pronotal disc parallel (Fig. 4G) . . . . . *leeiensis* sp. nov.

Lateral margins of pronotal disc convergent (Figs 3G, 4C) 16

16. Posterior margin of pronotal disc concave (Fig. 4C) . . . . . *webbensis* sp. nov.

Posterior margin of pronotal disc convex (Fig. 3G) . . . . . *baroalbaensis* sp. nov.

17. Lateral margins of pronotal disc parallel (Figs 3H,L, 4A-B) 18

Lateral margins of pronotal disc not parallel (Figs 3F,I-K, 4D-F) 21

18. Micropterous, forewings reaching T3. *micropterus* sp. nov.

Submacropterous, fore wings reaching apex of abdomen 19

19. Rim of vertex pit circular in dorsal view, lateral margins of pronotal disc not dilate (Figs 3H, 5H) . . . . . *finniganensis* sp. nov.

Rim of vertex pit triangular in dorsal view, lateral margins of pronotal disc dilate (Figs 3L, 4A, 5L, 6A) 20

20. Rim of vertex with notch anteromedially, strong intrusion of pronotal disc into pit (Fig. 4A) . *conwayensis* sp. nov.

Rim of vertex pit not notched, no intrusion of pit into pronotal disc (Fig. 3L). . . . . *allonesioticus* sp. nov.

21. Pronotal disc undulate (Fig. 6E) . *athertonensis* sp. nov.

Pronotal disc not undulate (Figs 5F,I-K, 6D,F) 22

22. Pronotal disc convex immediately above vertex pit (Fig. 7F) . . . . . *sidereoriensis* sp. nov.

Pronotal disc flat or concave immediately above vertex pit (Figs 7I-K, 8D,F) 23

23. Lateral margins of pronotal disc and humeral angle dilate (Figs 3I, 5I) . . . . . *polysperes* sp. nov.

Lateral margins of pronotal disc and humeral angle not dilate (Figs 3J-K, 4D,F) 24

24. Forewing concolourous . . . . . *lambensis* sp. nov.

Forewing with pale band or at least one pale basal cell. . 25

25. Vertex pit V-shaped in anterior view (Fig. 7K), pronotal disc sulcate above pit . . . . . *ancylonesioticus* sp. nov.

Vertex pit U-shaped in anterior view (Fig. 8D,F), pronotal disc broadly concave above pit. 26

26. Intrusion of pronotal disc into pit flattens, becomes horizontal, humeral angles tumid (Fig. 4D) . . . . . *pismaensis* sp. nov.

Intrusion of pronotal disc inclined in pit, not flattening, humeral angles barely tumid (Fig. 4F) . . . . . *allomelanoriensis* sp. nov.

Kaimon alleungellanus sp. nov.
(Figs 4J, 6J, 8J, 10E, 10H, 18B, Tables 2, 3)

ETYMOLOGY. Greek *allos*, other; 'other of Eungella' alludes to the shared distribution with *K. eungellanus*.

MATERIAL. TYPES. Holotype. T.108863: sub. ♂, Broken River, Eungella NP, 21°11'S 148°31'E, 700m, Monteith, 18 Apr 1979, OFSLB-QM35, carded ex ethanol, in QM. Paratypes: as for holotype, 1 sub. ♂, slide and vial, in QM. OTHER MATERIAL. Finch Hatton Gorge, 21°04'S 148°38'E, 470m, A. Gillison, 18 Nov 1981, 1 ♀; Finch Hatton Gorge, 21°04'S 148°38'E, 300m, A. Gillison, 18 Nov 1981, 1 sub. ♂; in ANIC. Palm Lookout, Eungella, 21°10'S 141°31'E, 700m, Monteith, 18 Apr 1979, 1 sub. ♂; in QM.

DESCRIPTION. *Submacropterous Male.* General colour brown, posterior quarter of disc lighter brown, vertex lobe yellow-brown. Vertex without pit but with U-shaped, slightly elevated yellowish brown lobe bounded by U slit.

Pronotal disc with small flat area adjacent to vertex lobe; disc in profile convex and decurved anteriorly, flat posteriorly, not concurvilinear with anterior profile; humeral angles not tumid; lateral margins parallel, not dilate. Metapleurae not prominent in dorsal view.

Forewings not paler proximally, 3 free veins subapically.

T1 microganulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule without tumescence on right posterior angle; left paramere 0.114mm. Conjunctival sclerites of aedeagus with short spinous process much shorter than basal plate

(Fig. 18B). Vesica single, incomplete loop, simple apex, no branch.

Female. Venation light brown, 1 cream, closed cell.

DISTRIBUTION. 3 localities in CQ at 300-700m. *K. eungellanus* and *K. conwayensis* also occur in CQ. Females from 3 series without males (swamp and sclerophyll palm forests, 6.5km SSE Eungella, 800 m) may be this species or *K. eungellanus*.

NOTES. Macropterous male unknown. Collected in open, vine and rain forest litter and stick brushing berlesates.

Kaimon allomelanoriensis sp. nov.
(Figs 1A, 1C, 1D, 4F, 6F, 8F, 14M, 19D, Tables 2, 3)

ETYMOLOGY. Greek *allos*, other; 'other from black mountain', refers to the shared distribution in the Black Mountain Corridor region with *K. melanoriensis*.

MATERIAL. TYPES. Holotype: sub. ♂, Black Mtn Rd, 30km N Kuranda, J.G. Brooks, 4 Nov 1969, RFLB-ANIC165, carded (sympatric in mount with paratype male of *K. melanoriensis*), in ANIC. Paratype: as for holotype, 2 sub. ♂, on multiple mount with holotype of *K. melanoriensis*, in ANIC. OTHER MATERIAL. Black Mtn Rd, 11km N Kuranda, Turkey Pocket, 30 Oct 1969, J.G. Brooks, 1 sub. ♂, 3 ♀, in ANIC.

DESCRIPTION. *Submacropterous Male*. General colour dark reddish brown, vertex with pale rim. Curvature of frons flattened; vertex pit in dorsal view pear-shaped, posterior margin formed by sharply excavate (or squarely incised) anteromedial margin of disc; in anterior view wide V- to arc-shaped, ridge and arch embracing ridge visible, anterior margin with acutely defined rim, not depressed, no depression anterior to pit, apex of pear-shaped pit formed between points of disc intrusion, medial ridge of pit broad, depressed and disjunct from anterior rim of pit; outer rim superior to intruding points of disc.

Pronotal disc embracing pit ridge, line between points of protrusion into pit concave with square notch in views perpendicular to disc and whole body axis. Disc protrusion inclined, not becoming horizontal apically; disc weakly concave above vertex pit; convex anteriorly and strongly decurved in lateral view, not concurvilinear with head profile; weakly convex-flat posteriorly but concurvilinear with anterior profile; humeral angles barely tumid; lateral margins weakly convergent in dorsal view, not dilate. Metapleurae not prominent in dorsal view.

Forewings variably pale proximally, in repose forming pale transverse band on body or merely a pale costal vein, 2 free veins subapically.

T1 granulate. Posterior margin S6 simple (Fig. 14M). Disc of S7 with very weak impression submedially and weak tumescence adjacently on right. Genital capsule with distinct tumescence on right posterior angle (Fig. 14M); left paramere long, 0.212mm. Conjunctival sclerites of aedeagus probably lacking spinous process. Vesica sinuous, not looped, vesica with subapical tooth; vesica with subequal, sinuous branch arising beyond midlength, branch apex simple

Female. See notes for *K. melanoriensis*. The females of the Turkey Pocket series listed as additional material and not sympatric in series with *K. melanoriensis* are brown, have 1-2 cream, closed, forewing cells and light brown to brown venation which is typical of many species.

DISTRIBUTION. From 2 rainforest sites 19km apart in the Black Mountain Corridor at unknown altitude. It is sympatric with *K. melanoriensis* at the type locality for both species.

NOTES. Macropterous male unknown. Collected in rainforest litter berlesates.

Kaimon allonesioticus sp. nov.
(Figs 3L, 5L, 7L, 17F, Tables 2-3)

ETYMOLOGY. Greek *allos*, other, *nesiotes*, islander; alluding to its sympatry with *K. ancylonesioticus*.

MATERIAL. TYPES. All in QM. Holotype T108857: sub. ♂, Gayundah Ck, Hinchinbrook I., 18°22'S 146°13'E, 80m, Monteith, Davies, Thompson & Gallon, 12 Nov 1984, RFSLB-QM669, carded. Paratypes: as for holotype, 1 sub. ♂ and 8 ♀ in 1 vial, 1 sub. ♂ on 1 slide, 1 ♀ carded, 1 ♀ cleared in vial.

DESCRIPTION. *Submacropterous Male*. General colour brown, vertex paler. Vertex pit in dorsal view roundly triangular, posterior margin formed by truncate apex of protruding disc margin; pit roundly V-shaped in anterior view, arch of disc protrusion embracing ridge visible, ridge not visible; anterior margin of pit not depressed, no depression anterior to pit, pit with acutely defined rim; medial ridge of pit recessed, disjunct from anterior rim of pit; curvature of frons weakly convex.

Pronotal disc flattened above vertex pit, inclining into pit but not notched or embracing pit ridge, apex of protrusion squarely truncate (without points), inferior to rim of pit; disc

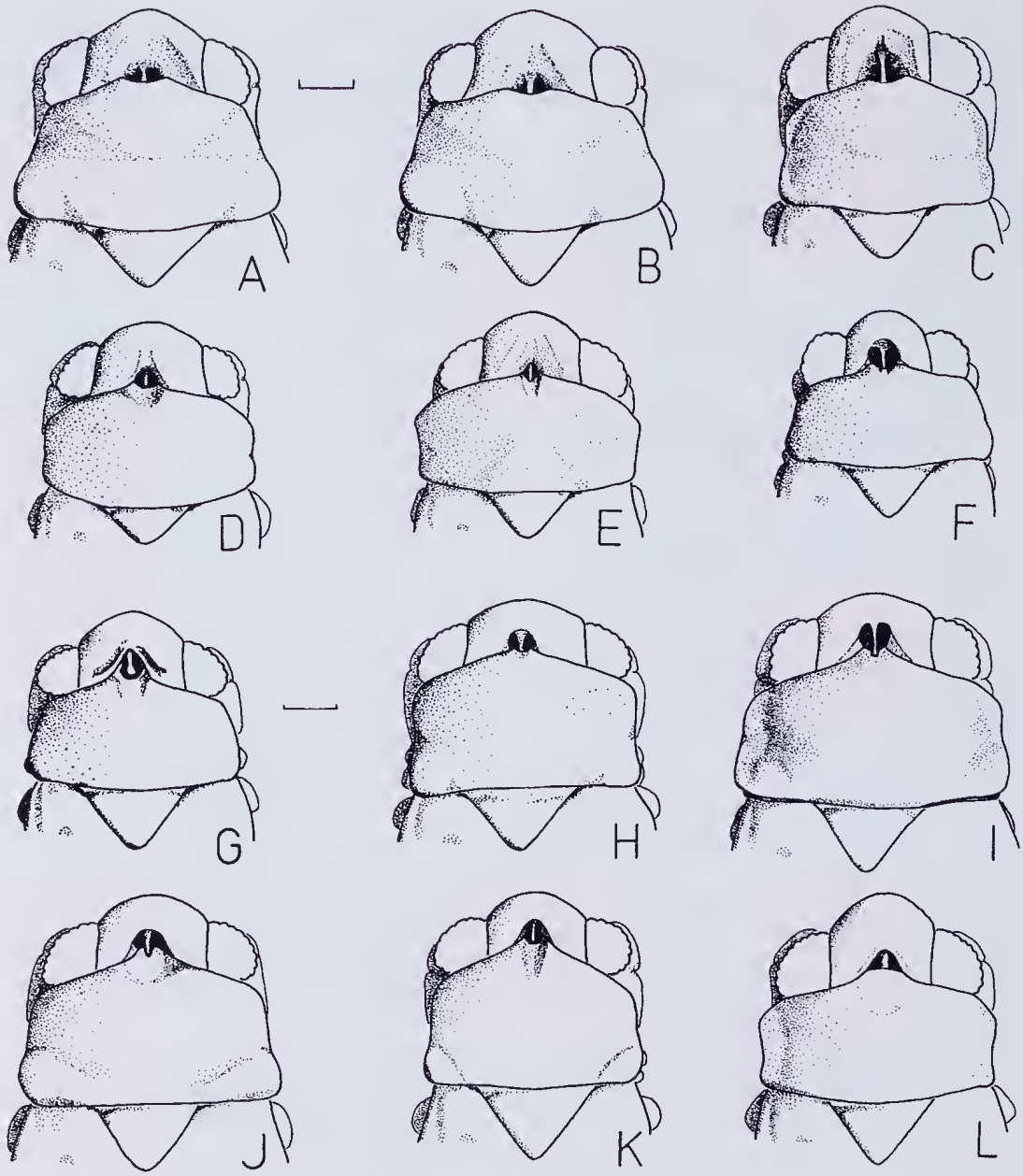

FIG. 3. Submacropterous ♂♂, anterior half, dorsal. A, *K. epicarsius*; B, *K. melanoriensis*; C, *K. thorntonensis*; D, *K. macdowallensis*; E, *K. carbinensis*; F, *K. sidereoriensis*; G, *K. baroalbaensis*; H, *K. finniganensis*; I, *K. polysperes*; J, *K. lambensis*; K, *K. ancylonesioticus*; L, *K. allonesioticus*. Scale lines 0.1mm.

convex anteriorly, weakly decurved in lateral view, concurvilinear with head profile; flat posteriorly and concurvilinear with anterior profile; humeral angles barely tumid; lateral margins roughly parallel but constricted at midlength in dorsal view, disc in dorsal view widest anteriorly, lateral margins dilate; posterior margin convex. Mesopleurae prominent in dorsal view.

Forewings entirely pale; 2 free veins subapically.

T1 carinulae in form of vestigial triangles, not clearly carinulate or granulate. Posterior margin S6 simple but S5 with minute, protruding ledge on right near midline. Disc of S7 with small impression submedially and distinct tumescence sublaterally on right reaching posterior margin, posterior margin weakly projecting on right. Genital capsule simple, right posterior corner with broad, illdefined tumescence; left paramere 0.139mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica biramous incomplete, spiralled loop, apex simple; vesica with subequal, branch arising distally, branch apex simple.

Female. Light brown, forewing with 1-2 cream, closed cells, veins light brown; pronotal and cibarial muscle scars dark.

DISTRIBUTION. Hinchinbrook Island at 80m compared to 10m for *K. ancylonesioticus*.

NOTES. Macropterous male unknown. Collected in a litter berlesate from rainforest.

Kaimon ancylonesioticus sp. nov.
(Figs 3K, 5K, 7K, 17E, 19I, Tables 2-3)

ETYMOLOGY. Greek ankylos, hooked, *nesiotes*, islander; referring to the hooked vesical apex and distribution on Hinchinbrook Island.

MATERIAL. TYPES. All in QM. Holotype T108856: sub. ♂, Gayundah Ck, Hinchinbrook I., 18°22'S 146°13'E, 10m, Davies, Thompson & Gallon, 9 Nov 1984, RFSLB-QM663, carded ex ethanol. Paratypes: as for holotype, 3 sub. ♂ and 11 ♀ in ethanol vial, 1 sub. ♂ carded, 2 ♀ carded, 1 sub. ♂ in 3 slides and 1 vial, 1 ♀ cleared and dissected in vial. OTHER MATERIAL. Gayundah Ck, Hinchinbrook I., 18°22'S 146°13'E, 10m, MT, 8-15 Nov 1984, 8 sub. ♂, 4 ♀, in 3 series, in QM.

DESCRIPTION. *Submacropterous Male*. General colour dark brown, vertex concolourous. Vertex pit in dorsal view roundly triangular, posterior wall formed by squarely emarginate protrusion of disc, V-shaped in anterior view, ridge barely visible but arch of disc protrusion embracing disc visible, anterior margin with acutely defined rim, not depressed, no depression anterior to pit, curvature of frons weakly flattened, medial ridge of pit recessed and disjunct from anterior rim of pit, lateral portions of pit rim superior to intruding points of disc.

Pronotal disc embracing but not touching pit ridge in dorsal and anterior views, points of anteromedial disc margin protruding into pit laterally, line between points of protruding disc squarely concave in views dorsal to disc and body axis; disc protrusion with sulcate incline into vertex pit; disc otherwise convex anteriorly and decurved in lateral view but concurvilinear with head profile; weakly convex posteriorly and concurvilinear with anterior profile; humeral angles tumid; lateral margins more or less parallel in dorsal view but appearing weakly convex if tumid angles considered, lateral margins not dilate. Metapleurae prominent in dorsal view.

Forewings entirely pale proximally; two free veins subapically.

T1 carinulate. Posterior margin S6 simple. Disc of S7 with small impression submedially on right bordered by weakly raised areas, posterior margin weakly projecting on right. Genital capsule with acute tumescence on right posterior angle; left paramere 0.147mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica not forming a loop, vesical apex simple; vesica with longer, sinuous, recurved branch, apex of branch minutely incised.

Female. Light brown, forewing with 2 cream, closed cells, veins light brown; pronotal and cibarial muscle scars dark.

DISTRIBUTION. Hinchinbrook Island at 10m compared with 80m for the next species, *K. allonesioticus*. Specimens examined late in this study from Mt Cleveland near Townsville in the Elliot Upland region are this or a closely allied species.

NOTES. Macropterous male unknown. Three series of females from Gayundah Creek, 10m not associated with males may be this species or the next. Collected in litter berlesates, flight intercept traps and yellow pan traps in rain forest.

Kaimon athertonensis sp. nov.
(Figs 4E, 6E, 8E, 17G, 19K, Tables 2, 3)

ETYMOLOGY. From the Atherton Uplands region.

MATERIAL. TYPES. Holotype. T108860: sub. ♂, Mt Fisher, 7km SW Millaa Millaa, 17°34'S 145°34'E, 1100m, Monteith, Yeates, Cook, 27 Apr 1982, RFSLB-QM409, carded, in QM. Paratypes: as for holotype, 1 sub. ♂ and 1 ♀ in vial, 1 sub. ♂ carded, 1 sub. ♂ in 1 slide and vial, 1 ♀ in 1 slide and vial, in QM. OTHER MATERIAL. Mt Fisher, 7km SW Millaa Millaa, 1050-1100m, MYC, 27-29 Apr 1982, 4 sub. ♂, 1 ♀, in 3 series (sympatry in 1 series with 1 mac. ♂ *K. polysperes*); Mt Fisher (Kjellberg), 17°32'S 145°33'E, 1100m, Monteith, 17 May 1995, 1 sub. ♂, 8 ♀ (sympatric in series with 1 mac. ♂ *K. polysperes*); in QM.

DESCRIPTION. *Submacropterous Male*. General colour brown, vertex concolourous.

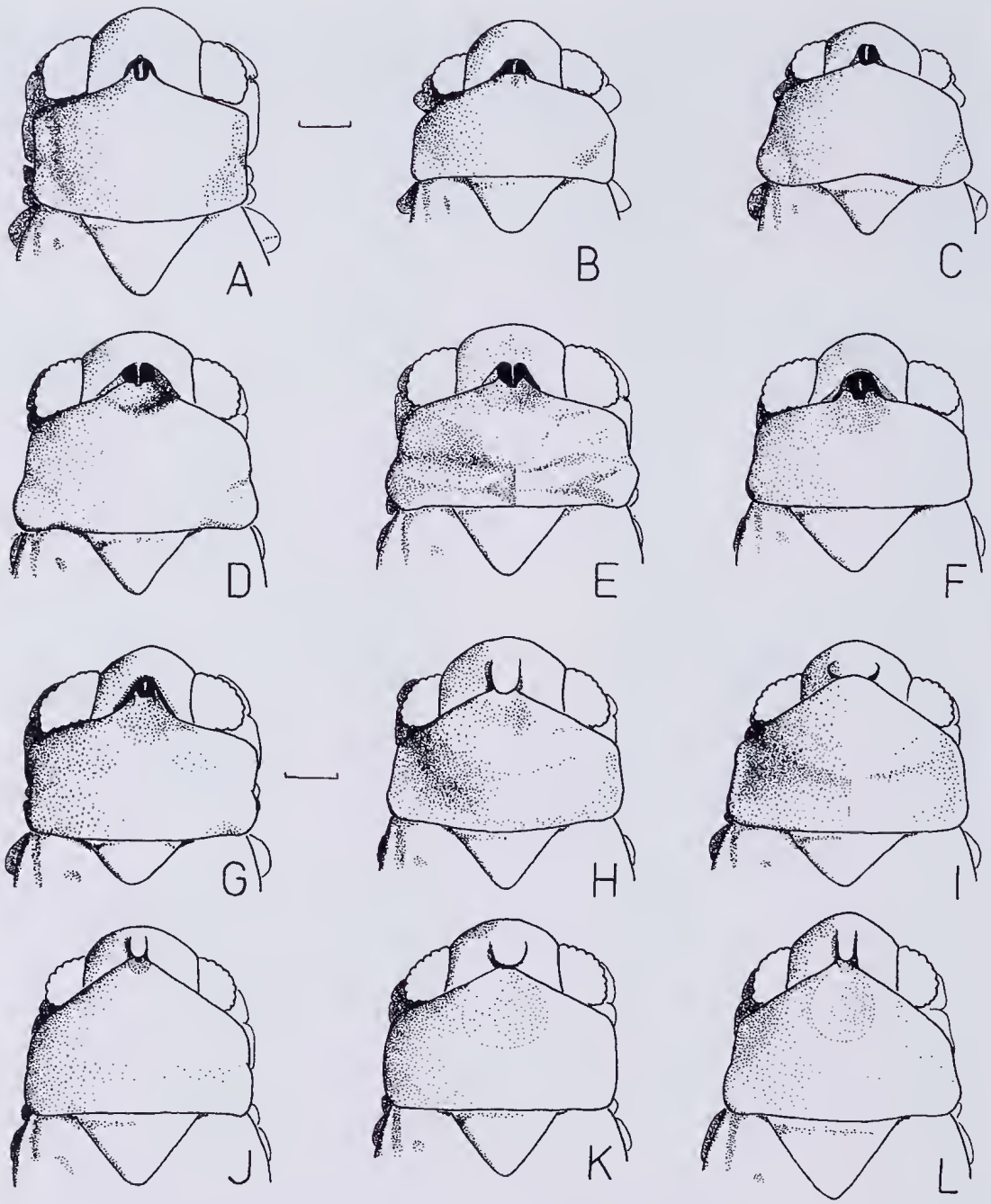

FIG. 4. Submacropterous ♂♂, anterior half, dorsal. A, *K. conwayensis*; B, *K. micropterus*; C, *K. webbensis*; D, *K. pismaensis*; E, *K. athertonensis*; F, *K. allomelanoriensis*; G, *K. leeiensis*; H, *K. eungellanus*; I, *K. kroombitensis*; J, *K. alleungellanus*; K, *K. notipolysperes*; L, *K. byfieldensis*. Scale lines 0.1mm.

Frons strongly flattened (Fig. 6E); vertex pit in dorsal view heart-shaped, posterior wall formed by flat, steeply inclined protrusion of disc, in anterior view arc-shaped, ridge and minute arch embracing ridge visible, anterior margin not depressed, anterior margin with acutely defined

rim, vertex not depressed anteriorly to pit, medial ridge of pit flush with rim and confluent with anterior rim of pit.

Pronotal disc loosely embracing pit ridge in dorsal view, points between V-shaped, emarginate anterior margin of protrusion concave in views perpendicular to disc and whole body axis and confluent with inner vertex pit rim in anterodorsal view; flat above vertex pit; anteriorly with transverse ridge rising to a central hump, anterior face parallel to profile of flat frons, posteriorly with transverse ridge, gutter separating major transverse ridges interrupted by medial, minor, longitudinal ridge; humeral angles tumid but merging with posterior, transverse ridge; lateral margins otherwise parallel in dorsal view, not dilate. Metapleurae not prominent in dorsal view.

Forewings paler proximally, in repose forming pale transverse band on body; 2 free veins subapically.

T1 granulate. Posterior margin S6 simple. Disc of S7 without depression, posterior margin weakly produced on right; genital capsule with weak tumescence on right posterior angle; left paramere 0.163mm. Conjunctival sclerites of aedeagus with very short spinous process much shorter than basal plate (Fig. 17G). Vesica incomplete, biramous, spiralled loop, apex with small tooth; subequal, cosinuate branch with simple apex.

Female. Venation brown, costa light brown, 1 cream, closed cell.

DISTRIBUTION. Mt Fisher in the Atherton Uplands region at 1050-1100m in rainforest where it is sympatric with *K. polysperes*.

NOTES. Macropterous male unknown. The pronotal disc is very distinctive. *K. athertonensis* is sympatric with macropterous males of *K. polysperes* in two series from Mt Fisher. The acute tumescence at the right corner of the male genital capsule of a macropterous male (1.2mm long) in series with submacropterous males of *K. athertonensis* suggests it is *K. polysperes*. If the macropter was *K. athertonensis* then it lacks any trace of the distinctive pronotal contours of the submacropter. *K. polysperes* is known by submacropterous males from another Mt Fisher series albeit not a series containing submacropterous males of *K. athertonensis*. The frons of *K. athertonensis* is more flattened than in most species. Collected in litter and stick brushing berlesates, pitfall traps and by pyrethrum knockdown in rainforest.

Kaimon baroalbaensis sp. nov.
(Figs 3G, 5G, 7G, Tables 2-3)

ETYMOLOGY. From Baroalba Springs.

MATERIAL. ANIC. Holotype: sub. ♂, Baroalba Spring, NT, 12°47'S 132°51'E, R.W. Taylor, 20 Nov 1972, RFB-ANIC470, carded. Paratypes: As for holotype, 5 ♀.

DESCRIPTION. *Submacropterous Male*. General colour light brown, vertex concolourous. Vertex pit roughly triangular in dorsal view, ill-defined posterior wall formed by intrusive inclined disc, broadly V-shaped in anterior view, arch of disc protrusion embracing pit ridge barely visible, anterior margin well defined but rounded rather than sharply defined, not depressed or raised but appearing labiate because depressed cibarial muscle scars form pitted moat parallel to rim; medial ridge of pit recessed and disjunct from anterior rim of pit.

Pronotal disc projecting into pit, embracing pit ridge in dorsal view; weakly impressed above pit; convex anteriorly and decurved in lateral view, not concurvilinear with vertex profile; flattening posteriorly but concurvilinear with profile of anterior disc; humeral angles not tumid but dilate; lateral margins convergent in dorsal view, not dilate. Metapleurae prominent in dorsal view.

Forewings not paler proximally; two veins subapically. Posterior margin S6 with long, narrow ledge. S7 impressed submedially on right but no adjacent tumescence, posterior margin weakly projecting on right. Genital capsule simple, right posterior corner without distinct tumescence; left paramere and conjunctival sclerites of aedeagus unknown. Vesica looped, vesical apex simple; vesical branch unknown.

Female. Colour generally light brown, forewings concolourous, 1 cream, closed cell.

DISTRIBUTION. From the Northern Territory.

NOTES. Macropterous male unknown. Known from 1 submacropterous male and 5 females. No slides were prepared for this description. Collected in a rain forest litter berlesate.

Kaimon bulburinensis sp. nov.
(Fig. 9F-H, Tables 2, 3)

ETYMOLOGY. From the Bulburin region.

MATERIAL. TYPES. Holotype. T108867: sub. ♂, Forest Station, Bulburin SF via Many Peaks, 2000 feet, Monteith, 2-5 Apr 1972, in QM. Paratypes: 2 ♀, on card mount with holotype, in QM.

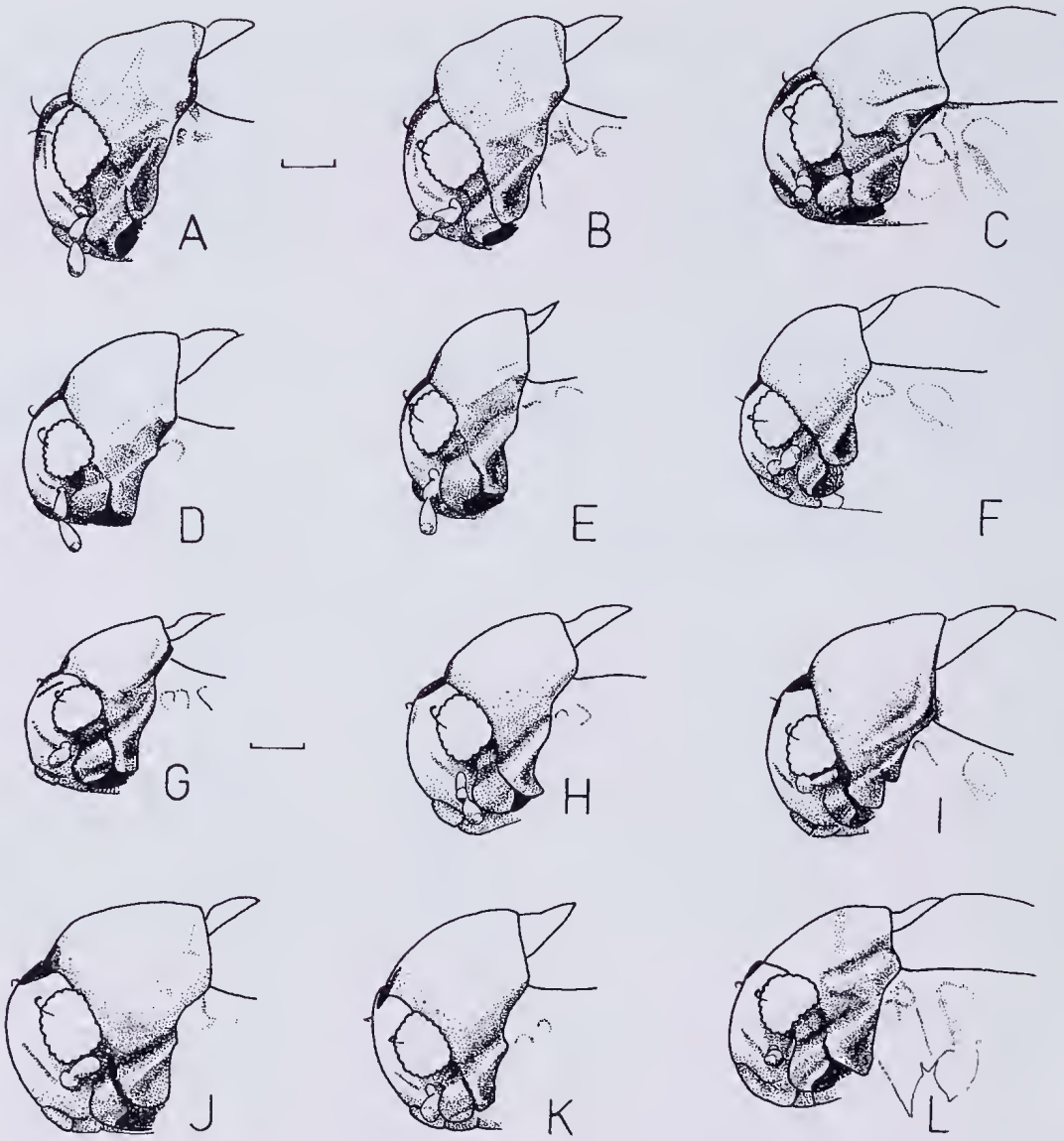

FIG. 5. Submacropterous ♂♂, anterior half, left lateral. A, *K. epicarsius*; B, *K. melanoriensis*; C, *K. thorntonensis*; D, *K. macdowallensis*; E, *K. carbinensis*; F, *K. sidereoriensis*; G, *K. baroalbaensis*; H, *K. finniganensis*; I, *K. polysperes*; J, *K. lambensis*; K, *K. ancylonesioticus*; L, *K. allonesioticus*. Scale lines 0.1mm.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, posterior quarter disc lighter brown, vertex with faint pale triangle medially, costa not yellow-brown but claval and sutellum margins yellow brown. Vertex without pit or lobe, perhaps a vestigial depression, narrow posterior area in profile colinear with pronotal disc but abruptly decurving anteriorly to frons.

Pronotal disc flattened adjacent to vertex pit vestige; anterior margin in dorsal view strongly deviating from straight line; disc in profile straight anteriorly and weakly convex posteriorly; humeral angles weakly tumid; lateral margins weakly convergent, not dilate. Metapleurae prominent in dorsal view.

Forewings without pale band proximally, 3 free veins subapically.

T1 unknown. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with broad, rounded tumescence on right posterior angle; left paramere unmeasured. Conjunctival sclerites of aedeagus unknown. Vesica forming single spiralled loop, apex simple, no branch.

Female. Venation brown, 1 cream closed cell, clavus with small, yellow-brown patch.

DISTRIBUTION. 1 locality in SQ at 650m. The closest congener is *K. kroombitensis* at Kroombit Tops.

NOTES. Macropterous male unknown. Collecting method and habitat unknown.

Kaimon byfieldensis sp. nov.
(Figs 4L, 6L, 8L, 18D, Tables 2, 3)

ETYMOLOGY. From the Byfield region.

MATERIAL. TYPE. Holotype. T108865: sub. ♂, Nob Creek, Byfield, 23°52'S 150°37'E, Monteith, 27 Apr 1979, RFSLB-QM72, carded ex ethanol, in QM. Paratypes: as for holotype, 3 ♀ (1 ♀ on 2 slides plus vial, other 2 ♀ in another vial). OTHER MATERIAL. Nob Creek, Byfield, 23°52'S 150°37'E, Monteith, 27 Apr 1979, 1 sub. ♂, 1 ♀ in 2 series; in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, vertex paler. Vertex without pit but with U-shaped, slightly elevated lobe bounded by U slit.

Pronotal disc with large concave area adjacent to vertex lobe; disc in profile barely inflated, weakly convex anteriorly and posteriorly; humeral angles weakly tumid; lateral margins anterior to humeral angles convergent and dilate. Metapleurae not prominent in dorsal view.

Forewings not paler proximally, 3 veins subapically.

T1 microganulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with distinct tumescence on right posterior angle; left paramere 0.098mm. Conjunctival sclerites of aedeagus with short spinous process much shorter than basal plate (Fig. 18D). Vesica single loop, simple apex, no branch (Fig. 18D).

Female. Posterior quarter of disc lighter brown than remainder of body, veins brown, 2 closed, cream cells.

DISTRIBUTION. 1 locality in CQ, remote from rainforest.

NOTES. Macropterous male unknown. Collected in rain forest litter and stick brushing berlesates.

Kaimon carbinensis sp. nov.
(Figs 3E, 5E, 7E, Table 2)

ETYMOLOGY. From the Carbine Uplands region.

MATERIAL. HOLOTYPE. T108853: sub. ♂, Mossman Gorge, 16°25'S 145°20'E, Monteith, 20 Oct 1982, RFSLB-QM263, carded ex ethanol, in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, vertex concolourous. Vertex pit diamond-shaped with posterior apex formed by sharply excavate anteromedial margin of disc in dorsal view. Anterior margin of vertex pit depressed, vaguely defined, V-shaped in anterior view, without notched apex, merging with narrow, shallow gutter diminishing towards frons. Medial ridge of pit recessed and disjunct with anterior margin of pit.

Anteromedial margin of pronotal disc forming posterior margin of vertex pit in dorsal view, points of sharply excavate margin confluent with depressed rim of vertex pit (forming posterior apex of diamond-shaped pit), embracing pit ridge in anterior but not dorsal view; anteromedial disc sulcate immediately above vertex pit; convex anteriorly and strongly decurved, not concurvilinear with vertex profile; flat posteromedially but smoothly continuous with anterior area; lateral margins in dorsal view roughly parallel, disc widest at about 0.25 from anterior margin, narrowest medially; lateral margins of disc not dilate; humeral angles not tumid; pronotal muscle scars depressed. Metapleurae not prominent in dorsal view.

Forewings not paler proximally; 2 free veins subapically.

T1 unknown. S6 margin simple. S7 lacking contiguous depression and tumescence on right, posterior margin weakly projecting on right. Genital capsule, left paramere and conjunctival sclerites of aedeagus unknown; vesica and concurved branch forming incomplete loop, vesica with subequal branch arising before midlength, apex of vesica or its branch bifid, other not.

DISTRIBUTION. One site in the Carbine Uplands region as one of 4 species in this region. Topotypic sympatry with one of the 2 widespread macropterous species of the Wet Tropics (Table

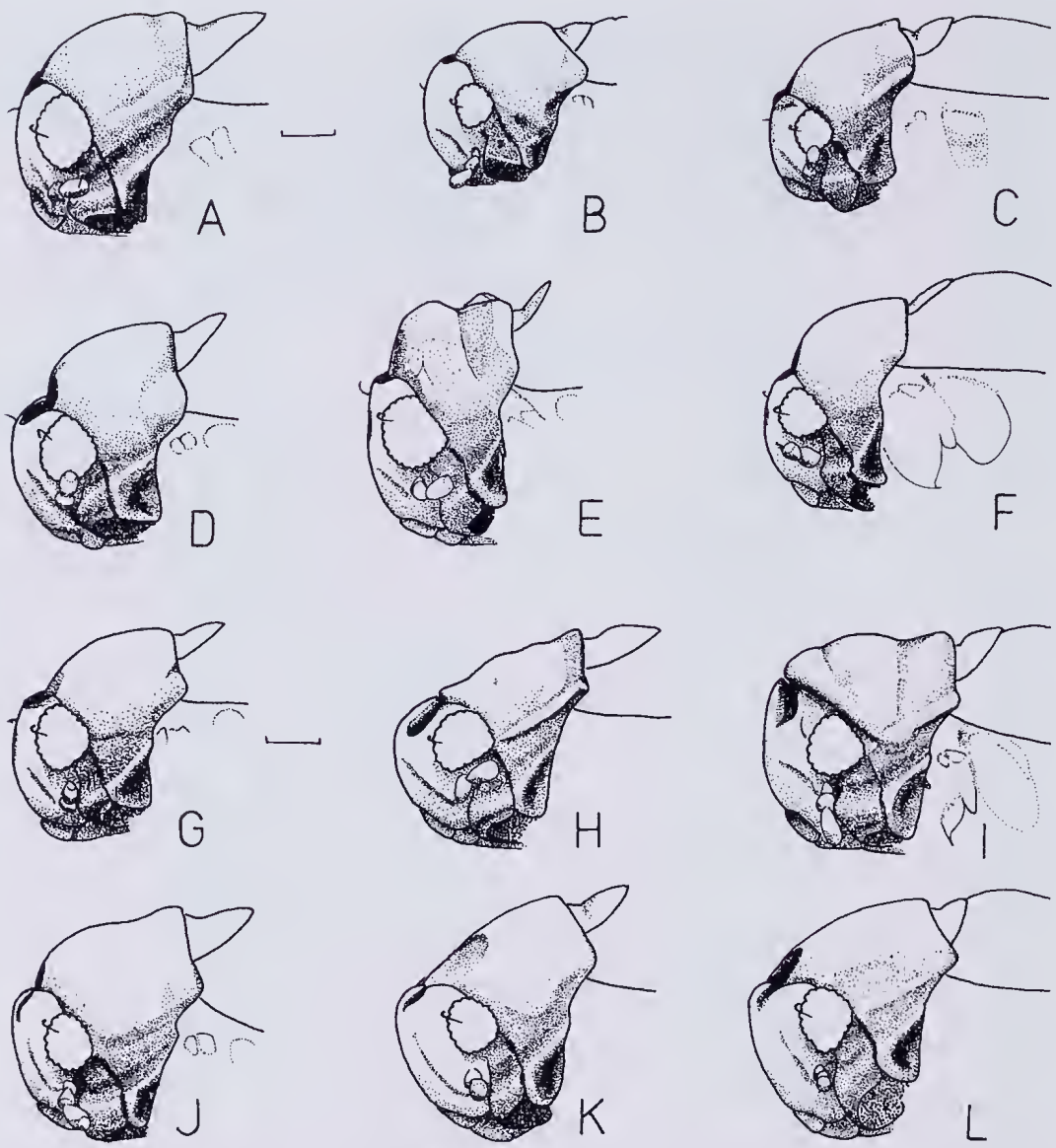

FIG. 6. Submacropterous ♂♂, anterior half, left lateral. A, *K. conwayensis*; B, *K. micropterus*; C, *K. webbensis*; D, *K. pismaensis*; E, *K. athertonensis*; F, *K. allomelanoriensis*; G, *K. leeiensis*; H, *K. eungellanus*; I, *K. kroombitensis*; J, *K. alleungellanus*; K, *K. notipolysperes*; L, *K. byfieldensis*. Scale lines 0.1mm.

4) is likely. *K. micropterus* occurs at another site adjacent to the Carbine Uplands region

NOTES. Female and macropterous male unknown. A solitary female in series with holotype was unusually large (male LB 82% of female LB) and is not regarded as conspecific. It has suitable dimensions (LB 0.95, LHT 0.45, WP 0.50, LP 0.21, DAE 0.41mm) to be either of the widespread macropterous species, *K. epicarsius* or *K. polysperes*, both of which occur in the Carbine Uplands region.

K. carbinensis has a similar vertex furrow anterior to the pit as in *K. thorntonensis* but it lacks a notched apex (Fig. 7C,E). The pronotal disc protrudes more into the pit to embrace the pit ridge creating a diamond-shaped rather than circular pit in dorsal view (Fig. 3C,E). The disc is

wider anteriorly and flat posteromedially in *K. carbinensis* rather than smoothly convex as in *K. thorntonensis* and *K. macdowallensis*.

Kaimon conwayensis sp. nov.
(Figs 4A, 6A, 8A, 16H, Tables 2-3)

ETYMOLOGY. From the Conway Range region.

MATERIAL. TYPES. All in QM. Holotype. T108858: sub. ♂, Brandy Ck, Conway SF, 20°20'S 148°42'E, 60m, Monteith, 23 Apr 1979, RF stick brushing B-QM56, carded. Paratypes: as for holotype, 2 ♀ in vial, 1 ♀ cleared in vial, 1 ♀ carded. OTHER MATERIAL. Brandy Ck, Conway SF, 20°20'S 148°42'E, 60m, Monteith, 23 and 25 Apr 1979, 1 sub. ♂, 1 ♀ in 2 series, in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark blackish brown, vertex concolourous. Vertex pit in dorsal view like pointed arch, posterior wall sinuate, formed by deeply emarginate protrusion of disc, V-shaped in anterior view, arch in disc protrusion visible, ridge not visible; anterior margin not depressed, acutely defined, faintly upcurved except medially (creating notched effect in some views); vertex not depressed anteriorly to pit, medial ridge of pit recessed, obscure, disjunct from anterior rim of pit.

Anteromedial margin of pronotal disc projecting into vertex pit as two, salient points, in dorsal view forming acute posterior apex to pit rather than arc-shaped posterior wall, line between points of protruding disc deeply concave in views dorsal to disc and body axis; disc weakly sulcate above vertex pit; convex anteriorly and weakly decurved in lateral view, concurvilinear with head profile; flat posteriorly and slightly depressed; humeral angles tumid; lateral margins roughly parallel but constricted at midlength in dorsal view, dilate. Mesopleura prominent in dorsal view.

Forewings probably not pale proximally (specimen stained by blue label dye); 2 free veins subapically.

T1 granulate. Posterior margin S6 simple. Disc of S7 with small impression submedially and weak tumescence sublaterally on right reaching posterior margin, posterior margin weakly projecting on right. Genital capsule with large, acute tumescence on right posterior angle; left paramere 0.171mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica spiralled-looped, vesical apex perhaps notched; with subequal, concurved branch arising near midlength, branch apex simple.

Female. Veins brown, 1 cream, closed, cell, spermatheca oblong.

DISTRIBUTION. CQ at 60m. Females not associated with males in 2 series from Mt Dryander (RF, 575m) and Cannon Vale (RF, 10 m) probably belong to this species but could be *K. eungellanus* or *K. alleungellanus* which occur 70-90km S in the Eungella area at 200-700m.

NOTES. Macropterous male unknown. The anteroventral macroseta of the hind tibiae may lie immediately distally of the posteroventral macroseta. Collected in litter and stick brushing berlesates from rain forest including dry rain forest.

Kaimon epicarsius sp. nov.
(Figs 2A, 3A, 5A, 7A, 10A-C, 11A-D, 12C,D, 13E,F,H,I, 14A-E, 15D-F,H,I, 16A-D, Tables 2-3)

ETYMOLOGY. Greek *epi-*, over and *karsios*, crosswire, meaning 'right-angled'; alluding to the distinctive vesica.

MATERIAL. TYPES. All in ANIC. Holotype: sub. ♂, C. Tribulation area, 16°03'S 145°28'E, Calder & Weir, 21-28 Mar 1984, RF on steep slope, B-ANIC944, carded. Paratypes: as for holotype, 19 sub ♂, 13 ♀. OTHER MATERIAL. All in ANIC: Mt Sampson, 15°48'S 145°12'E, 27 Jan 1990-18 Jan 1991, 1 mac. ♂; C. Tribulation area, 16°00'-16°05'S 145°28'E, 21-28 Mar 1984, Calder & Weir, 1 mac. ♂, 16 sub. ♂, 16 ♀ in 5 series; 13km NW Kuranda, 6 Dec 1982, J. Doyen, 2 sub. ♂, 8 ♀; 1.5km E by N Mt Sorrow, 16°05'S 145°S27'E, Calder & Weir, 25 Mar 1984, 1 sub. ♂, 1 ♀; Noah Ck, 7km ENE Thornton Peak, 16°08'S 145°26'E, Calder & Weir, 27 Mar 1984, 1 sub. ♂, 5 ♀; Black Mtn Rd, 400m, Calder & Weir, 30 Mar 1984, 2 sub. ♂, 1 ♀; 2km N by E Mt Tip Tree, 17°03'S 144°37'E, 800m, Calder & Weir, 4 mac. ♂, 10 sub. ♂, 16 ♀; Josephine Falls, Mt Bartle Frere, 17°27'S 145°52'E, 10 Jul 1984, B. Halliday, 2 sub. ♂, 1 ♀; Mt Tip Tree Q, 17°03'S 145°37'E, 13 Jul 1984, B. Halliday, 1 mac. ♂, 1 sub. ♂, 3 ♀; Mt Finnigan S1, 30km S Cooktown, 400m, Peck, 1 Jul 1982, RFL and fungi B, 17 sub. ♂, 12 ♀; C. Tribulation, 40km N Daintree, 10m, Peck, 12 Jul 1982, 2 sub. ♂, 9 ♀; C. Tribulation, 10m, Peck, 15 Jul 1982, 1 sub. ♂, 1 ♀; Lake Barrine, 750m, Peck, 29 Jul 1982, 1 sub. ♂.
All in QM: Mossman Bluff, 5-10km W Mossman, 250-860m, MT/ANZSES, Jan and Dec 1988, Jan and Dec 1989, Jan 1990, 2 mac. ♂, 12 sub. ♂ in 7 series (of which 2 series sympatric with *K. polysperes*); Davies Ck, Atherton Tbld, J.H. Connell, 10 July 1970, 1 sub. ♂, 1 ♀; Bellenden Ker Range, cableway base station, 100m, EQM, 17 Oct 1981 - 9 Nov 1981, 1 mac. ♂, 1 ♀; Big Tbld 15°43'S 145°17'E, 740m, 8 Jan 1991, ANZSES, 2 mac. ♂; Big Tbld 15°43'S 145°17'E, 740m, 9 Jan 1991, ANZSES, 1 mac. ♂; Lacey's Ck, Mission Beach, 18°52'S 146°03'E, 50m, Monteith, 9 Apr 1979, 1 sub. ♂, 1 ♀; Windin Falls, NW Mt Bartle-Frere, 580m, Monteith, 9 Oct 1980, 2 mac. ♂, 14 ♀ (sympatric in series with *K. polysperes*); Lyons Lookout, Rex Highway, Mossman, 400m, Monteith &

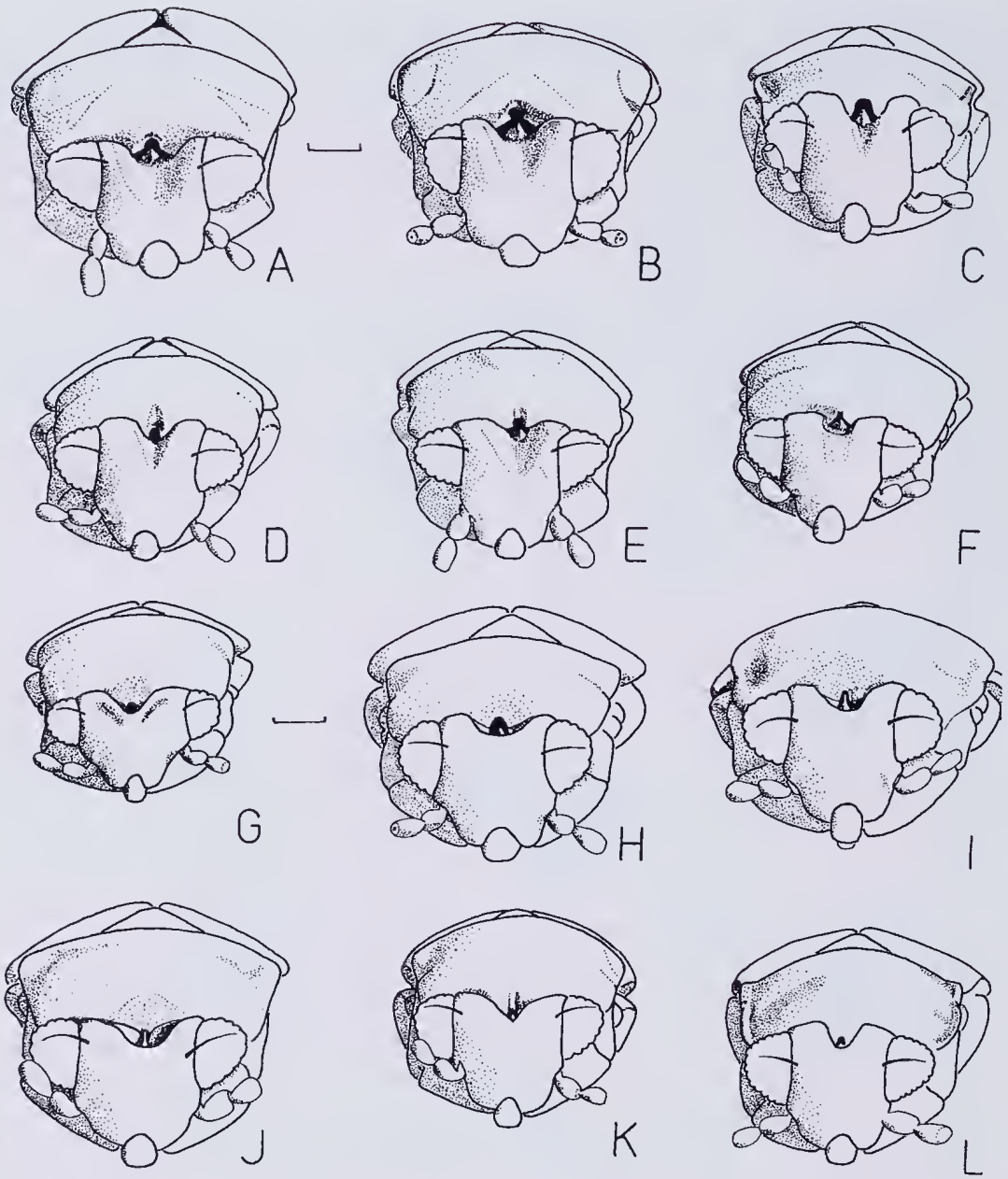

FIG. 7. Submacropterous ♂♂, anterior half, anterior. A, *K. epicarsius*; B, *K. melanoriensis*; C, *K. thorntonensis*; D, *K. macdowallensis*; E, *K. carbinensis*; F, *K. sidereoriensis*; G, *K. baroalbaensis*; H, *K. finniganensis*; I, *K. polysperes*; J, *K. lambensis*; K, *K. ancylonesioticus*; L, *K. allonesioticus*. Scale lines 0.1mm.

Cook, 13 Sep 1981, 1 mac. ♂; Russell R. at Bellenden Ker Landing, 17°16'S 145°.57'E, 5m, EQM, 1 Nov 1981, 1 mac. ♂; 1.5-3km W-NW C. Tribulation (sites 1, 2, 4 and 6), 16°05'S 145°27'-28'E, 0-500m, Sep-Oct 1982 and Jan-Apr 1983, MYT, 1 mac. ♂, 6 sub. ♂, 16 ♀ in 8 series; Boulder Ck via Tully, 18°50'S 145°54'E, 650m, MYT, 27 Oct 1983, RFSLB, 1 sub. ♂; McDowall Range, 17km N Daintree, 16°06'S 145°20'E, 520m, Monteith, 27 Nov 1985, 1 sub. ♂ (sympatric in series with *K. macdowallensis*); Black Mtn Rd, 5km N Kuranda, 16°47'S 145°38'E, 1200m, MT, 2 Dec 1988, 1 sub. ♂; Davies Ck Rd, 17°03'S 145°36'E, 750m, 17 Dec 1987,

MT, 1 mac. ♂, 2 ♀; Mt Gorton, 16°57'S 145°53'E, 750m, Janetzki, 18 Nov 1993, 1 mac. ♂; Hughes Rd, Topaz district, 17°26'S 145°42'E, 650m, Monteith & Janetzki, 5 Dec 1993, 2 sub. ♂, 3 ♀ (sympatric in series with *K. polysperes*).

DESCRIPTION. *Submacropterous Male.* General colour dark, reddish brown, vertex concolourous or occasionally paler medially.

Rim of vertex pit squarish with curved posterior margin formed by disc in dorsal view; rim ill-defined, widely opened U-shape in anterior view, pit in wide, shallow depression of vertex diminishing toward frons; medial ridge of pit recessed but confluent with anterior rim of pit.

Pronotal disc embracing ridge in vertex pit in anterior view but not intruding into pit in dorsal view, points of excavate anteromedial disc margin rounded and confluent with vertex pit rim in anterodorsal view, line between points concave in dorsal view perpendicular to disc but more or less straight in a dorsal view perpendicular to whole body axis, anteromedial face of disc convexly vertical above pit; disc convex anteriorly, sloping steeply to lateral margins, strongly decurved in lateral view, not concurvilinear with vertex profile; convex posteriorly but not coplanar with anterior section (weak discontinuity in profile); humeral angles tumid; lateral margins convergent in dorsal view, lateral margins not dilate. Metapleurae not prominent in dorsal view.

Forewings paler proximally, in repose forming pale transverse band on body (anterior vein pale proximally, dark distally, other veins dark proximally, pale medially and dark distally, cells pale proximally, dark distally, tiny costal cell dark); 2-3 free veins subapically.

T1 carinulate. S6 margin symmetrical; S7 with contiguous depression and tumescence on right near posterior margin, posterior margin weakly produced on right. Genital capsule simple, right posterior corner without distinct tumescence; left paramere 0.135-0.151mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica much longer than vesical branch, vesical branch apex with tiny, subapical, tooth; combined vesica and branch sinuous (not looped), with three right-angled bends in different planes proximally and one recurvature distally; vesica and branch diverge at first right-angle bend.

Macropterous Male. Disc similar to submacropter (vertically convex above vertex pit and anteromedially) but larger and smoothly convex in lateral view (Fig. 2A), humeral angles tumid, lateral margins convergent, not dilate; symmetry of S6, contours of S7 and genital capsule angles same as submacropter. Length fore wing 0.97mm, WP 0.60mm, LP 0.34mm, length overall 1.12mm.

Female. As in generic description; forewing cells cream, veins light brown, forewing with 0-2 closed cells (Fig. 13H-I shows 0-1 closed cells in one individual).

DISTRIBUTION. In 9 regions (Table 4) at 0-1200m altitude. It is one of 2 widespread species, the other being *K. polysperes*. Both are macropterous. 5 sympatric series were encountered. *K. epicarsius* is sympatric with *K. polysperes* at 4 localities, namely Mossman Bluff at 600m and 760m elevation, Windin Falls at 580m and Hughes Rd, Topaz District at 650m and with *K. macdowallensis* in McDowall Range at 520m. *K. epicarsius* and *K. pismaensis* occur at Bellenden Ker cableway base station at 100m but were not collected in a sympatric series.

NOTES. The vesica is unusual in not forming an incomplete loop. *K. epicarsius* looks like *K. melanoriensis* but the latter has a different and unusual vesica which is tightly recurved (Fig. 18F). One specimen from Mt Finnigan illustrates the unstable venation found in many Schizopteridae in that the posterior vein of the forewing anastomoses subapically with the intermediate vein on right but not left wing (Fig. 13E,F). *K. epicarsius* was collected in berlesates of leaf litter, leaf and fungi litter, streamside flood litter and stick brushings, flight intercept traps and by pyrethrum knockdown in rain forest, lowland rain forest, littoral rain forest and *Araucaria* forest.

Kaimon eungellanus sp. nov.
(Figs 4H, 6H, 8H, 10F, 14G, 17D, Tables 2, 3)

ETYMOLOGY. From the Eungella region.

MATERIAL. ANIC. Holotype: sub. ♂, 2.5km ESE Eungella, 21°08'S 148°31'E, 200m, A. Gillison, 18 Nov 1981, tall open woodland LB-ANIC/C24, carded ex ethanol. Paratypes: 3 sub. ♂ and 9 ♀ in vial, 1 ♀ carded, 1 sub. ♂ in slide and vial, 1 ♀ in slide and vial.

DESCRIPTION. *Submacropterous Male.* General colour dark brown but vertex lobe and costal veins yellow brown. Frons curvature not flattened. Vertex without pit, with elevated, U-shaped lobe bounded by U-slit.

Pronotal disc concave adjacent to vertex lobe; disc deflated, not decurved anteriorly, with undulating contours, posteriorly upcurved;

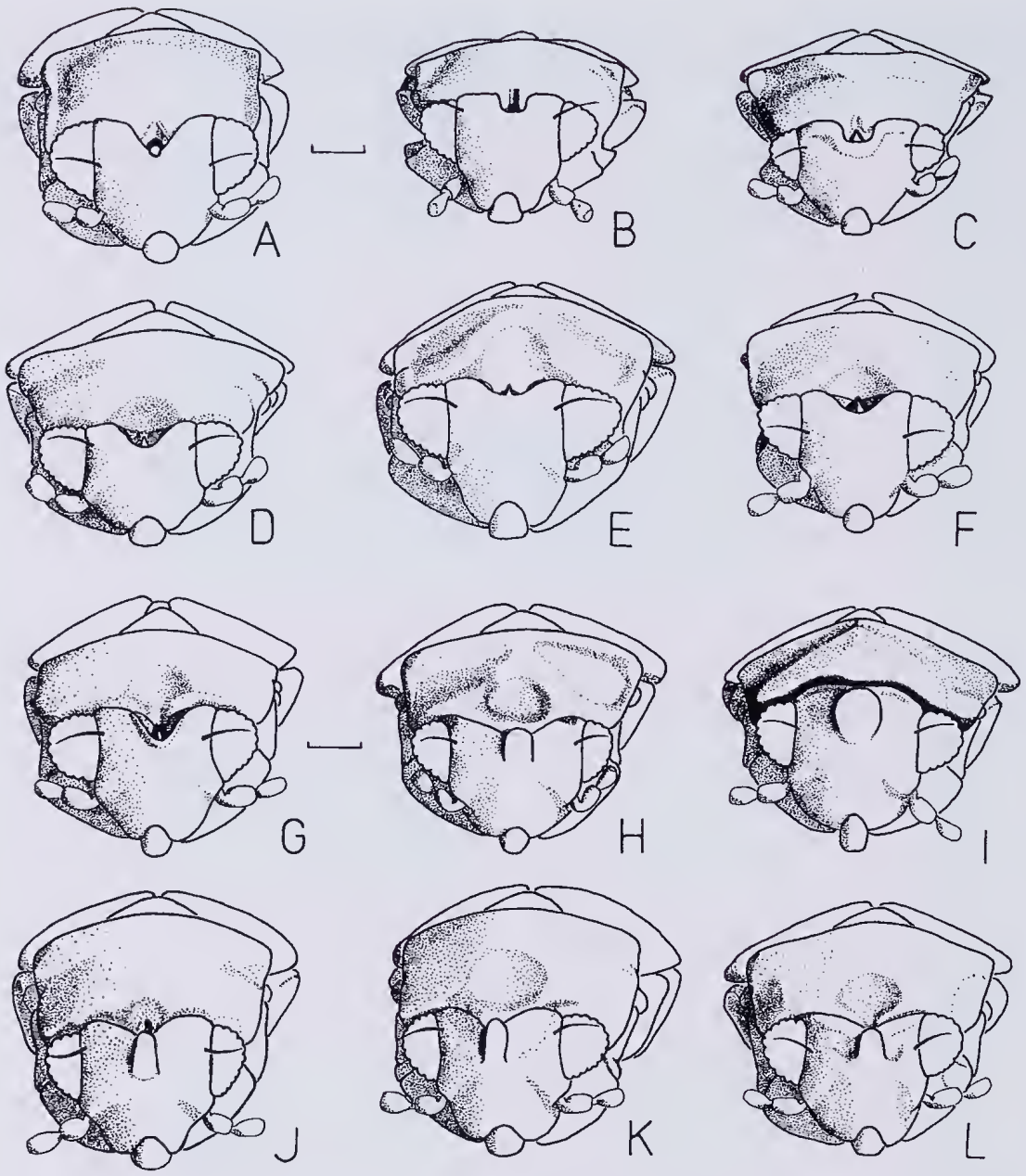

FIG. 8. Submacropterous ♂♂, anterior half, anterior. A, *K. conwayensis*; B, *K. micropterus*; C, *K. webbensis*; D, *K. pismaensis*; E, *K. athertonensis*; F, *K. allomelanoriensis*; G, *K. leeiensis*; H, *K. eungellanus*; I, *K. kroombitensis*; J, *K. alleungellanus*; K, *K. notipolysperes*; L, *K. byfieldensis*. Scale lines 0.1mm.

humeral angles not tumid; lateral margins roughly parallel (weakly convergent), dilate; posterior margin broadly deflexed and dilate for entire length. Metapleurae not prominent in dorsal view.

Forewings not paler proximally but costal vein yellow brown, 3 free veins subapically.

T1 microgranulate. Posterior margin S6 with intruded ledge submedially on left; right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with procurved, spinous tumescence on right posterior angle; left paramere 0.127mm. Conjunctival sclerites of aedeagus uncertain. Vesica incomplete loop, simple apex, no branch.

Female. Humeral angles, anteromedial diac area and apex scutellum yellow brown, veins brown except proximal costa yellow brown, I pale, closed cell. Spermatheca biglobular.

DISTRIBUTION. 1 locality in CQ at 200m. *K. alleungellanus* and *K. conwayensis* also occur in CQ. Females from 3 series without males (swamp and sclerophyll palm forests, 6.5km SSE Eungella, 800 m) may be this species or *K. alleungellanus*.

NOTES. Macropterous male unknown. In a slide preparation of a paratype male S5-7 bear a longitudinal, sublateral, slit passing through the intruded ledge on S6 margin. The slit may be an artefact of slide preparation associated with an abrupt change in disc contour. Collected in an open forest litter berlesate.

Kaimon finniganensis sp. nov.
(Figs 3H, 5H, 7H, 14I, 15J, 19J, Tables 2-3)

ETYMOLOGY. From the Finnigan Uplands region.

MATERIAL. QM. Holotype T108855: sub. ♂, Mt Finnigan summit via Helenvale, 1050m, Monteith, Sheridan, Roberts & Thompson, 3-5 Dec 1990, PK, carded. Paratypes: as for holotype, 2 sub. ♂ carded. OTHER MATERIAL. Mt Finnigan via Helensvale, 850-950m, Cook, Thompson & Roberts, 3-5 Dec 1990, 1 sub. ♂, 1 ♀; Mt Finnigan summit via Helensvale, 1050m, ditto, 1 sub. ♂; Mt Finnigan 37km S of Cooktown 15°49'S 145°17'E, 900m, Monteith, Yeates, Cook, 22 Apr 1982, 1 sub. ♂, 4 ♀; Mt Finnigan, 37km S. Cooktown, 15°49'S 145°17'E, 1050m, Monteith, Yeates, Thompson and Cook, 21 Apr 1982, 2 sub. ♂ and 2 ♀ (lost during observation); in QM.

DESCRIPTION. *Submacropterous Male*. General colour yellowish brown to brown, vertex concolourous but rim of pit dark if specimen pale. Vertex pit in dorsal view circular, posterior margin formed by excavate anteromedial margin of protruding disc, arc-shaped in anterior view, anterior margin not depressed, clearly defined but without acute rim, no depression anterior to pit but curvature of frons flattened; medial ridge of pit recessed, disjunct from anterior rim.

Protrusion of pronotal disc embracing pit ridge in anterior view and widely embracing pit ridge in dorsal view; points of disc protrusion projecting into pit laterally, confluent in anterodorsal view with vertex pit rim but inferior to it, line between points concave in dorsal views perpendicular to disc and perpendicular to whole body axis; disc flat immediately above pit; disc convex anteriorly and strongly decurved in lateral view, not concurvilinear with vertex profile; weakly convex posteriorly and concurvilinear with anterior profile; lateral margins parallel in dorsal view except tumid humeral angles; lateral margins not dilate. Metapleurae prominent in dorsal view. Mesopleural tumescences at level of metapleural shelf conspicuously dark tipped.

Posteroventral macroseta on hind tibiae short (1.1 tibial diameters).

Forewings paler proximally but pale cells and veins not contrasting strongly with darker distal veins and cells; 2 free veins subapically.

T1 granulate medially, carinulate laterally. Posterior margin S6 with small asymmetric projection right of midline (Fig. 14I). Disc of S7 without tumescence, posterior margin sinuous, moderately produced on right. Genital capsule with tumescence on right posterior angle (Fig. 14I); left paramere unmeasured. Conjunctival sclerites of aedeagus with spinous process as long as basal plate (Fig. 15J). Vesica not looped but incurved subbasally and subapically; vesica with subequal incurved branch arising near midlength, vesica or branch apically bifid.

Female. Brown, forewings paler, 1 cream, closed cell.

DISTRIBUTION. Mt Finnigan at 850-1050m.

NOTES. Macropterous male unknown. Collected in litter berlesates, pitfall traps and by pyrethrum knockdown in rain forest.

Kaimon kroombitensis sp. nov.
(Figs 4I, 6I, 8I, 14N, Tables 2, 3)

ETYMOLOGY. From the Kroombit Tops region.

MATERIAL. TYPES. Holotype. T108862: sub. ♂, site 10, Kroombit Tops, 45km SSW Calliope, 24°23'S 150°56'E, 720m, Monteith, Davies, Thompson & Gallon, 11 Dec 1983, RFSLB-QM628, carded ex ethanol, in QM. Paratypes: 1 sub. ♂ and 3 ♀ in vial, 1 sub. ♂ in slide and vial, 1 ♀ in slide and vial, as for holotype, in QM. OTHER MATERIAL. Kroombit Tops, 45km SSW Calliope, sites 6, 11, 14 and another, 24°22'-24'S 150°56'-151°01'E, 880-940m, 10-14 Dec 1983, Monteith, Davies, Gallon & Thompson, 1 sub. ♂, 6 ♀ in 4 series; Dan Dan Scrub,

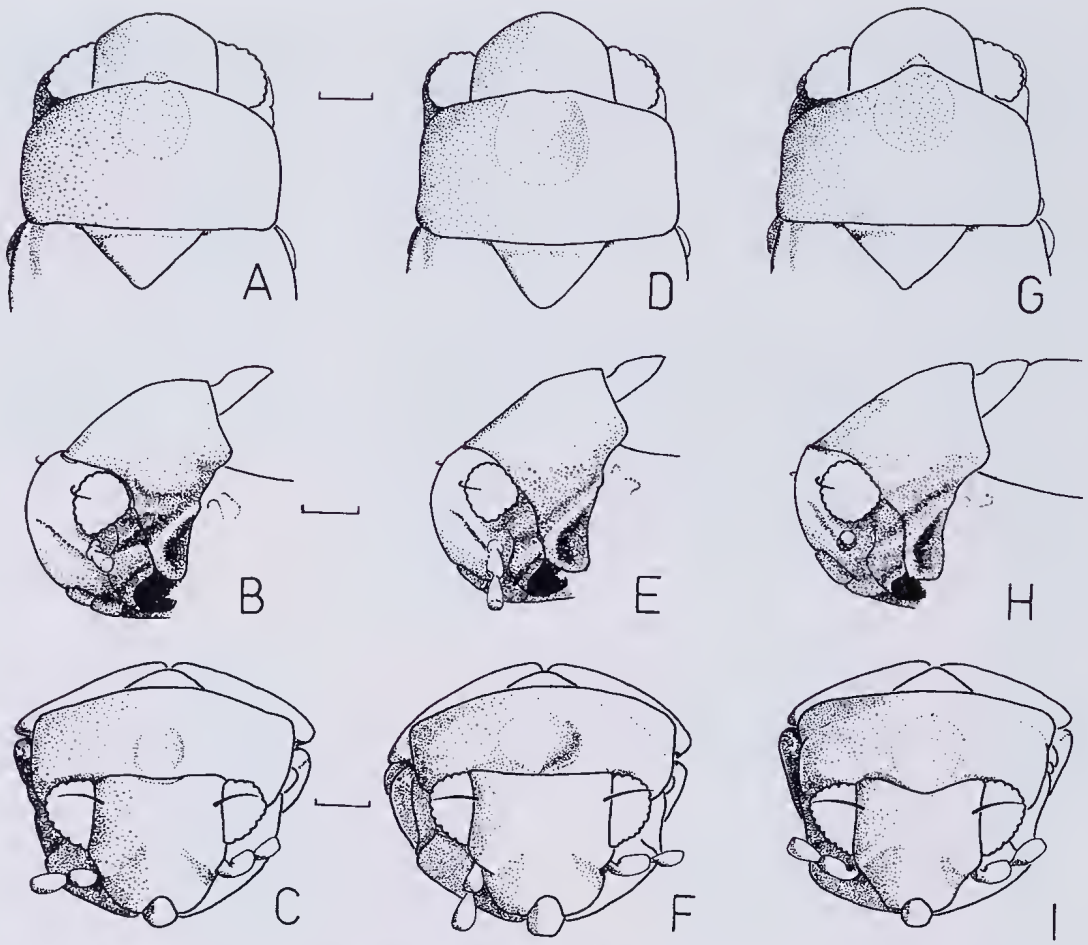

FIG. 9. Submacropterous ♂♂, anterior half, dorsal, left lateral and anterior views. A-C, *K. plistonotius*; D-F, *K. mesambrinus*; G-I, *K. bulburinensis*. Scale lines 0.1mm.

21km SSW Calliope, site 1, 24°10'S 151°05'E, 100m, Monteith, Davies, Gallon & Thompson, 14 Dec 1983, 1 ♀; in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, vertex lobe yellow-brown, posterior eighth of disc lighter brown. Vertex without pit but with U-shaped, broad lobe, oriented vertically, bounded by U slit.

Pronotal disc with anterior margin partially overhanging vertex lobe; disc in profile with two convex sections anteriorly, flat posteriorly; humeral angles not tumid; lateral margins weakly convergent-parallel, dilate. Metapleurae conspicuous in dorsal view.

Forewings not pale proximally, 3 free veins subapically.

T1 microganulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with broad rounded tumescence on right posterior angle; left paramere 0.135mm. Conjunctival sclerites of aedeagus with short spinous process much shorter than basal plate. Vesica single loop, simple apex, no branch

Female. Posterior quarter of disc, veins and scutellum apex lighter brown than remainder of body, forewing with 1 cream, closed cell.

DISTRIBUTION. 4 sites at Kroombit Tops and nearby lowland Dan Dan Scrub in SQ at 100-940m.

NOTES. Macropterous male unknown. Collected in open and rain forest litter berlesates.

Kaimon lambensis sp. nov.
(Figs 3J, 5J, 7J, Tables 1, 2)

ETYMOLOGY. From the Lamb Range.

MATERIAL. TYPE. Holotype: sub. ♂, Mt Tip Tree, 17°03'S 145°37'E, B. Halliday, 13 Jul 1984, RF yellow trap, 1 sub. ♂, carded ex ethanol, in ANIC.

DESCRIPTION. *Submacropterous Male.* General colour dark reddish brown, vertex concolourous. Vertex pit in dorsal view semicircular anteriorly, ill-defined posteriorly by gently inclined protrusion of anteromedial margin of disc, U-shaped in anterior view, ridge visible but no arch in anteromedial disc margin embracing ridge in anterior view, anterior margin of pit acute, not depressed, no depression anterior to pit, medial ridge of pit conspicuous but weakly recessed and disjunct with anterior rim of pit.

Pronotal disc projecting broadly into vertex pit, apices of protrusion incised, intimately embracing pit ridge, line between broad points of protrusion deeply incised; disc broadly and clearly weakly concave above vertex pit, inclining into pit; convex anteriorly and strongly decurved in lateral view, not concurvilinear with head profile; almost flat posteriorly but colinear with anterior profile; humeral angles tumid; lateral margins weakly convergent in dorsal view, not dilate. Metapleurae prominent in dorsal view.

Forewings without pale band subbasally; 2 free veins subapically.

T1 unknown. Posterior margin S6 simple. S7 without contiguous tumescence and depression on right side, posterior margin weakly projecting on right. Genital capsule simple, right posterior corner probably distinctly tumescent; left paramere unmeasured. Conjunctival sclerites of aedeagus and vesica unknown.

DISTRIBUTION. 1 locality at Mt Tip Tree in the Lamb Uplands at an unknown elevation.

NOTES. Female and macropterous male unknown. Collected in rain forest yellow trap. *K. epicarsius* was also found at Mt Tip Tree by the same collector on the same date but in a litter berlesate. No slides were prepared for this description.

Kaimon leeiensis sp. nov.
(Figs 4G, 6G, 8G, Tables 2, 3)

ETYMOLOGY. From the Lee Uplands region.

MATERIAL. HOLOTYPE. T108861: sub. ♂, Wallaman Falls via Ingham, 500m, Monteith, 1 Oct 1980, RF stick brushing B-QM231, carded ex ethanol, in QM.

DESCRIPTION. *Submacropterous Male.* General colour light brown, rim of vertex pit darker, apex of scutellum and bases of forewing veins paler. Curvature of frons weakly flattened (Fig. 6G). Vertex pit in dorsal view triangular, posterior margin formed by squarely excavate margin of disc protrusion; in anterior view roundly V-shaped, ridge and arch of disc embracing ridge barely visible, anterior margin with acutely defined, raised rim, medial ridge of pit recessed below rim and disjunct from anterior rim of pit.

Pronotal disc protrusion closely embracing pit ridge; weakly concave to flat above pit with inclined area protruding into pit; line between points of protrusion apeparing briefly straight; disc convex anteriorly and inclined in lateral view, not concurvilinear with head profile; weakly convex posteriorly and concurvilinear with anterior profile; humeral angles not tumid; in dorsal view lateral margins roughly parallel but faintly constricted at midlength, not dilate. Pronotal scars weakly impressed. Metapleurae prominent in dorsal view.

Forewing veins light brown distally, yellow brown proximally (also scutellum), all cells pale (no pale band effect when wings in repose), 2 free veins subapically.

T1 carinulation unknown. Posterior margin S6 simple. Disc of S7 with weak impression submedially and weak tumescence sublaterally on right. Genital capsule with distinct tumescence on right posterior angle; left paramere unknown. Conjunctival sclerites of aedeagus unknown. Vesica unknown.

DISTRIBUTION. 1 rainforest site at Wallaman Falls in the Lee Uplands region at 500m. Here, it is sympatric with *K. polysperes*, but was collected in a sieved litter berlesate series rather than a stick brushing berlesate series. It is also sympatric with an undescribed species known by 1 macropterous male from Wallaman Falls Road (in QM).

NOTES. Female and macropterous male unknown. Two tumescences on mesopleurae at the level of antennal shelf are more conspicuous than in most species because their dark apices contrast with the generally light colour of this species. Collected by rainforest stick brushing berlesate.

Kaimon macdowallensis sp. nov.
(Figs 3D, 5D, 7D, Table 2)

ETYMOLOGY. From the McDowall Range.

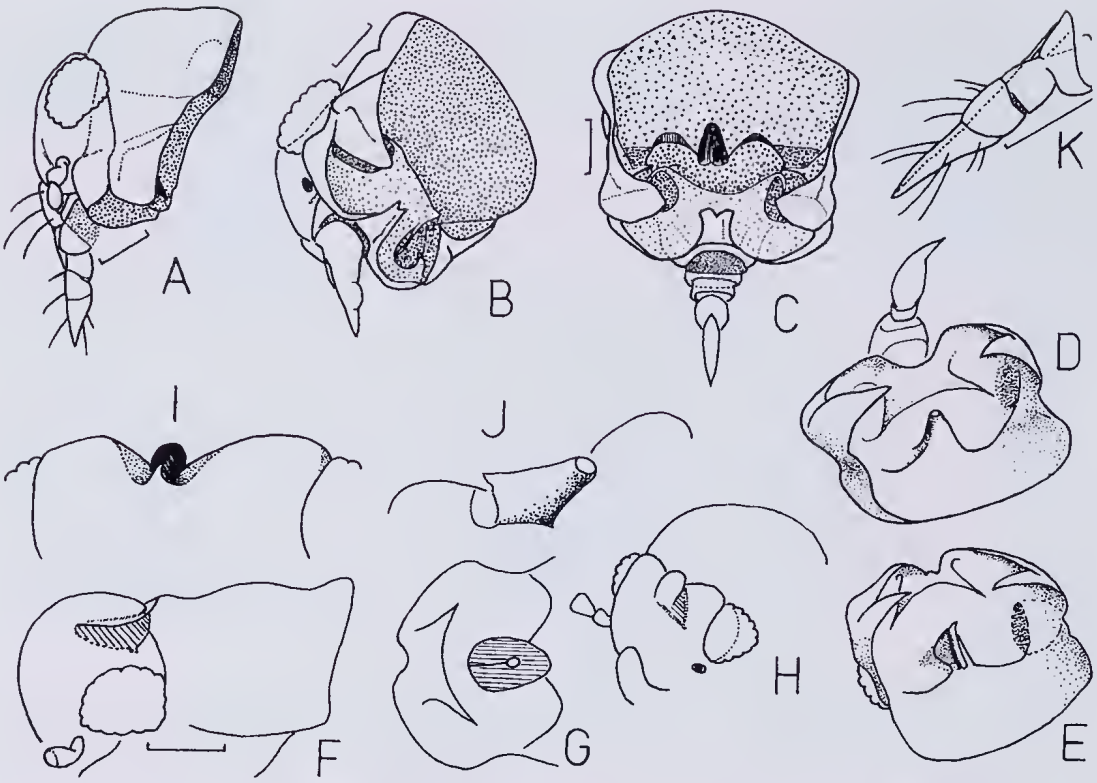

FIG. 10. A-C, head and pronotum, submacropterous ♂, *K. epicarsius*; A, left lateral; B, ventrolateral; C, ventral; D, same, *K. thortonensis* posteroventral; E, same, *K. alleungellanus*; F, same, *K. eungellanus*, lateral, internal vertex organ shaded; G, same without head, ventral; H, same, *K. alleungellanus*, left anterolateral; I-J, ♂ vertex organ, *K. athertonensis*, anterolateral; I, external; J, internal; K, labium, left anterolateral. Scale lines 0.1mm; sketches D-J not to scale or roughly to scale.

MATERIAL. HOLOTYPE. T108852. sub. ♂, McDowall Range, 17km N Daintree, 16°06'S 145°20'E, 520m, Monteith, 27 Nov 1985, RFSLB-QM684, carded, in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, vertex concolourous. Rim of vertex pit in dorsal view oval to diamond-shaped, posterior wall formed by sharply excavate anteromedial margin of disc, V-shaped in anterior view with embracing arch of disc protrusion clearly visible above obscured medial ridge of pit, pit rim depressed, indistinct and merging with shallow V-shaped depression diminishing toward frons; medial ridge of pit recessed and disjunct with anterior rim of pit.

Anteromedial margin of pronotal disc forming posterior margin of vertex pit in dorsal view, points of sharply excavate margin confluent with depressed rim of vertex pit (forming posterior apex of diamond-shaped pit), embracing pit ridge in anterior but not dorsal view; anteromedial disc sulcate immediately above vertex pit; convex anteriorly and decurved in lateral view, concurvilinear with vertex profile; weakly convex posteriorly but concurvilinear with anterior profile; humeral angles not tumid; lateral margins parallel in dorsal view, not dilate. Metapleurae prominent in dorsal view.

Forewings not pale proximally; 2 veins subapically.

T1 unknown; posterior margins S5 and S6 simple; S7 disc unknown, posterior margin weakly projecting on right. Genital capsule simple, right posterior corner without distinct tumescence; left paramere and conjunctival sclerites of aedeagus unknown. Vesica in form of incomplete loop; vesica probably with long branch; apex of branch or vesica bifid.

DISTRIBUTION. One site in the Thornton Uplands region but not one of the many at which *K. thorntonensis* occurs. *K. macdowallensis* is

known only from the holotype which was sympatric in series with a submacropterous male of *K. epicarsius*.

NOTES. Female and macropterous male unknown. The holotype was moved from ethanol to a card and retained intact. The genitalia was not slided. Collected by rain forest sieved litter berlesate.

Kaimon melanoriensis sp. nov.
(Figs 1B, 3B, 5B, 7B, Table 2)

ETYMOLOGY. Greek melanos, black, oros, mountain; from Black Mountain.

MATERIAL. ANIC. Holotype: sub. ♂, Black Mtn Rd, 30km N Kuranda, J.G. Brooks, 4 Nov 1969, ANIC165, carded on multiple mount with 2 sub. ♂ that are paratypes of *K. allomelanoriensis*. Paratypes: 1 sub. ♂, as for holotype, carded on multiple mount with 1 sub. ♂ that is the holotype of *K. allomelanoriensis* and 1 indeterminate ♀. OTHER MATERIAL. None but females carded on multiple mounts with specimens of *K. allomelanoriensis* (listed below) may be *K. melanoriensis*.

DESCRIPTION. *Submacropterous Male.* As for *K. epicarsius* but 3 veins subapically, T1 unknown, genital capsule with small tumescence on right posterior corner; genitalia not examined in slide mount, left paramere roughly 0.084mm (stereomicroscope measure only, not slide mount), conjunctival sclerites of aedeagus unknown, vesica tightly recurved (neither spiralled or sinuous) (Fig. 18F), vesical apex unknown; vesica perhaps with short proximal branch.

Female. See notes.

DISTRIBUTION. 1 locality in the Black Mountain Corridor region where it was sympatric in series with *K. allomelanoriensis*.

NOTES. *K. melanoriensis* looks like *K. epicarsius* but the latter has a different and unusual vesica which is sinuous. Macropterous male unknown. The types are on 2 multiple card mounts also bearing 3 males of *K. allomelanoriensis*. These 2 mounts belong to a series of 4 multiple card mounts containing *K. melanoriensis* and *K. allomelanoriensis*. The other 2 mounts each bear 2 indeterminate females. The habitat is unknown but the ANIC165 code implies collection by leaf litter or similar berlesate.

Kaimon mesambrinus sp. nov.
(Figs 9D-F, 14K, 16I, 19H, Tables 2, 3)

ETYMOLOGY. Greek *mesembria*, south; alluding to the distribution of this species.

MATERIAL. Holotype. T108866: sub. ♂, Mt Coot-tha, Monteith, 13-20 Mar 1971, carded in triple mount with 2 sub. ♂ paratypes (holotype central, 1 paratype damaged, mostly lost), in QM. Paratypes: as for holotype, 2 sub. ♂, on card mount with holotype, 2 sub. ♂ and 8 ♀ on three card mounts, in QM.

DESCRIPTION. *Submacropterous Male.* General colour brown, posterior quarter disc lighter brown, vertex with yellow-brown triangle medially. Curvature of frons not flattened, vertex without pit or lobe, without vestigial depression, posterior vertex in profile colinear with pronotal disc but abruptly decurving anteriorly to frons (Fig. 9E).

Pronotal disc clearly and broadly flattened anteromedially, anterior margin with vestigial medial emargination; anterior margin in dorsal view weakly deviating from straight line; disc in profile straight anteriorly and weakly convex posteriorly; humeral angles not tumid; lateral margins parallel, not dilate. Metapleurae prominent.

Forewings without pale band proximally, 3 free veins subapically.

T1 microganulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with broad rounded tumescence on right posterior angle; left paramere 0.122mm. Conjunctival sclerites of aedeagus with short spinous process (Fig. 16I). Vesica forming single spiralled loop, apex simple, no branch.

Female. Veins light brown to brown, 1-2 closed, pale cells.

DISTRIBUTION. 1 locality in SQ at low altitude. The more widespread, macropterous *K. notipolysperes* occurs at surrounding localities within a 30km radius. A female from Petrie, 4-5 Sep 1965, B. Cantrell (in QM), could be either species.

NOTES. Macropterous male unknown. One paratype male with aberrant spur vein on right forewing emerging marginally between clavus and apex. Collecting method and habitat unknown.

Kaimon micropterus sp. nov.
(Figs 4B, 6B, 8B, 13G, 15C,K, Tables 2-3)

ETYMOLOGY. Greek *micro-*, small, *pteron*, wing; for micropterous forewings of males.

MATERIAL. TYPES. All in ANIC. Holotype: micropterous ♂, 1km N Rounded Hill, 15°17'S 145°13'E, Calder & Weir, 5-7 May 1981, OFLB-ANIC725, carded.

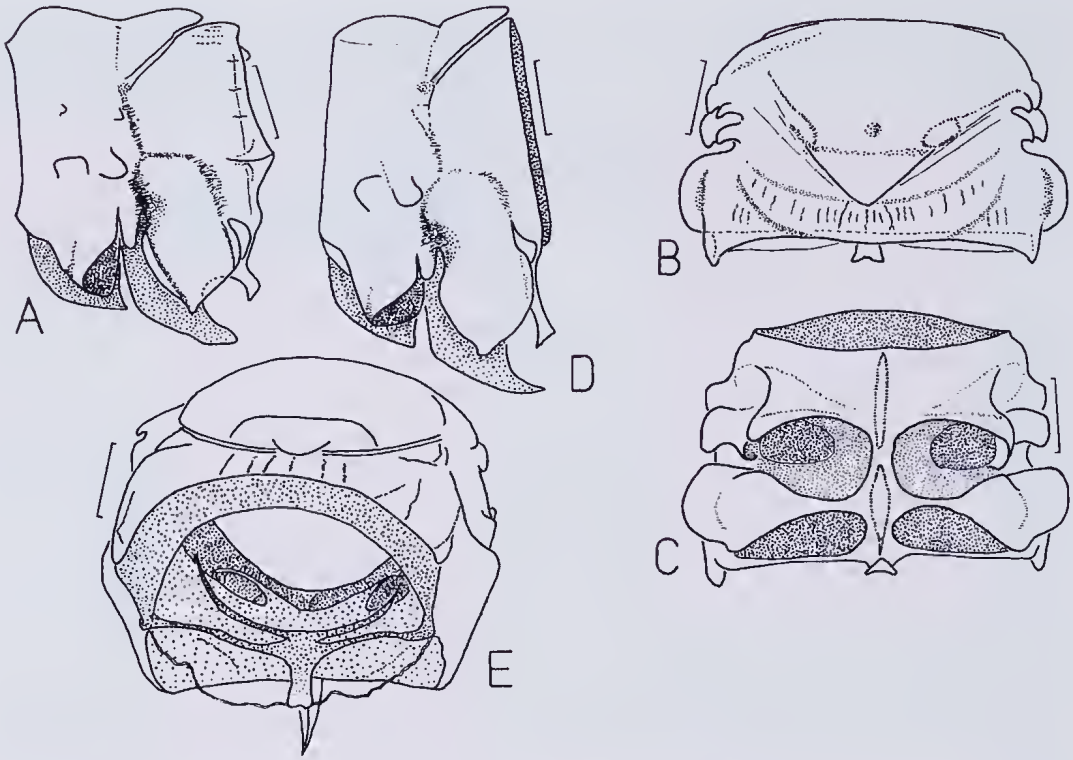

FIG. 11. Pterothorax. A-D, *K. epicarsius*; A-C, submacropterous ♂; A, lateral; B, dorsal; C, ventral; D, ♀; E, *K. polysperes* submacropterous ♂, right posterodorsolateral view. Scale lines 0.1mm.

Paratypes: as for holotype, 1 micropterous ♂ and 3 ♀ in vial, 1 ♀ cleared in vial, 1 micropterous male in 1 slide and vial, 1 ♀ carded. OTHER MATERIAL. 1km N Rounded Hill, 15°17'S 145°13'E, Calder & Weir, 5-7 May 1981, 4 micropterous ♂, 1 ♀ in ANIC. Bakers Blue Mtn, 820m, ANZSES, 1-18 Jan 1990, 1 micropterous ♂, in QM.

DESCRIPTION. *Micropterous Male*. General colour brown, vertex paler. Vertex pit (inner margins) in dorsal view square, posterior wall formed by straight margin of protruding disc, in anterior view square, ridge and arch in disc embracing ridge not visible, anterior margin not depressed, with acutely defined rim, vertex not depressed anteriorly to pit, medial ridge of pit recessed but confluent with anterior rim of pit.

Proepimeral shelves very wide, posterior angle in dorsal view rectilinear not absent or acute. Pronotal disc convex above vertex pit (but fine seta create impression of shallow sulcus in some views), inclining into pit but not embracing pit ridge, apex of protrusion squarely truncate (without points), inferior to rim of pit; disc convex anteriorly, weakly decurved in lateral view, concurvilinear with head profile; flat posteriorly and concurvilinear with anterior section; lateral margins in dorsal view parallel posteriorly but convergent anteriorly because of truncate angles, not dilate anteriorly, merging into descending pillar-like contour midway and overhanging posteriorly (Fig. 6B), humeral angles weakly tumid but not evidently so in dorsal view. Metapleurae prominent in dorsal view and sharing prominent angulate profile of propleural shelves in anterodorsal view.

Forewings reaching posterior margin T3, veins brown, except costa light brown proximally, 2 closed pale cells.

T1 carinulae reduced to granulate texture (Fig. 15C); carinulae of T2-6 short, half or less tergal width. Posterior margin S6 with long, narrow, symmetrical ledge. Disc of S7 with distinct tumescence sublaterally on right near posterior margin, posterior margin weakly projecting on right. Genital capsule simple, right posterior corner without distinct tumescence; left paramere 0.114mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica sinuous, not looped, vesical apex simple; vesica

with subequal, sinuous branch arising near midlength, branch apex simple.

Female. Propleural angles not rectangular in dorsal view, venation brown, 1 small, closed cell.

DISTRIBUTION. The disjunct distribution in open forest of Mt Webb region and in rainforest 150km S at Bakers Blue Mountain near the Carbine Uplands region raises doubt about the conspecificty of the latter male with the type series given the frequency of short range endemism or vicariance in other nonmacropterous species of this genus and the family in general. *K. webbensis* occurs about 30km to the north of the type locality of *K. micropterus*.

NOTES. Submacropterous and macropterous males unknown. This is the only species with a micropterous male. The forewings are marginally larger than those of females of this genus. They are too short, in not reaching T6, to be described a brachypterous. Collected in litter berlesates from open forest and a pitfall trap in rainforest.

Kaimon notipolysperes sp. nov.
(Figs 2D,E, 4K, 6K, 8K, 12A,B, 19E, Tables 2, 3)

ETYMOLOGY. Greek *notios*, southern, *poly-*, many, *speres*, sites; refers to its occurrence at many SQ and adjacent localities.

MATERIAL. Holotype. T108864: sub. ♂, nr Poona Lake, Cooloola NP, 26°00'S 153°06'E, Calder, 18 Apr 1982, carded ex ethanol, in QM. Paratypes: as for holotype, 20 sub. ♂, 17 ♀ in vial, 1 sub. ♂ carded, 2 ♀ carded, 1 sub. ♂ in slide plus vial, 1 ♀ in slide plus vial, 1 nymph, in ANIC, OTHER MATERIAL. Three 3 sub. ♂ and 3 ♀ were removed from the type series and sent to Australian Museum, Sydney for scanning electron micrography. All southern Queensland except Wiangaree which is New South Wales. Camp Milo, Cooloola NP, 26°00'S 153°05'E, Calder, 15-18 Apr 1982, 15 ♂, 43 ♀, 2 nymphs in 3 series; Balfour Range, 5km E Benarkin, 25°53'S 152°11'E, L. Hill, 19 Jun 1982, 1 sub. ♂, 2 ♀; 5km E Yarraman (Pidna), 26°52'S 152°03'E, L. Hill, 19 un 1982, 1 sub. ♂; Yabba Ck Forest, 7km SW Kenilworth, 150m, Peck, 15 Aug 1982, 1 sub. ♂; Wiangaree SF, 33km NE Wiangaree, NSW 1000m, Peck, 1 sub. ♂; in ANIC. Acacia Ridge, Brisbane, Sep 1962, E.B. The, 1 sub. ♂; Canungra Ck, 4 ml S Canungra, 14 Mar 1971, Monteith, 1 sub. ♂, 2 ♀; Dingo Ck via Traveston, GB. & S.R. Monteith, 30 Dec 1974 - 27 Mar 1975, 2 mac. ♀; Cold Ck via Imbil, GB. & S.R. Monteith, 1 mac. ♂; Top of Blackbutt Ra., Benarkin, GB. & S.R. Monteith, 1 sub. ♂; Freshwater Rd, Cooloola nr Rainbow Beach, 25-27 Apr 1975, Naumann, 2 ♀; Rainbow Beach, Cooloola, A. Postle, 17 Apr 1976, 3 sub. ♂; Stony Ck via Samford, 27°20'S 152°48'E, Janetzki & Monteith, 22 Oct 1994 - 2 Feb 1995, 1 sub. ♂, 1 ♀; Blackbutt Range, 5km E Benarkin, Gallon & Thompson, 30 Mar 1983, 2 ♀; in QM

DESCRIPTION. *Submacropterous Male*. General colour dark reddish brown, vertex lobe yellow-brown, venation brown but costa and 2V yellow-brown. Frons profile almost perpendicular to vertex. Vertex without pit but with U-shaped, elevated lobe bounded by U slit.

Pronotal disc with large flat to weakly concave area adjacent to vertex lobe; disc in profile flat to weakly convex anteriorly, almost flat posteriorly; humeral angles not tumid; lateral margins parallel, not dilate. Metapleurae not prominent in dorsal view.

Posteroventral macroseta on hind tibiae long (2.8 tibial diameters).

Forewings not paler proximally, 3 free veins subapically.

T1 microganulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with distinct tumescence on right posterior angle; left paramere 0.131mm. Conjunctival sclerites of aedeagus with short spinous process much shorter than basal plate (Fig. 19E). Vesica single loop, simple apex, no branch (Fig. 19E).

Macropterous Male. Anterior disc profile straight, colinear with vertex profile, posterior disc profile convex.

Female. Brown, posterior quarter of disc lighter brown, forewing with 1 closed, cream cell.

DISTRIBUTION. 12 localities in SQ and 1 in N NSW between sea level and 1000m. *K. mesambrinus*, for which no macropter is known, occurs within the range of this species at 1 site in SQ, namely Mt Coot-tha. A female from nearby Petrie, 4-5 Sep 1965, B. Cantrell (in QM), could be either species.

NOTES. Collected in rain forest litter (including scrub turkey mound litter) berlesates, flight intercept traps and pitfall traps and a wet sclerophyll flight intercept trap.

Kaimon pismaensis sp. nov.
(Figs 4D, 6D, 8D, 15B, 18A, Tables 2, 3)

ETYMOLOGY. Greek *peisma*, ship's cable; refers to the cableway in the Bellenden Ker – Bartle Frere Range Uplands region.

MATERIAL. HOLOTYPE. T108859: sub. ♂, Bellenden Ker Range, 0.5km S cable tower 7, 500m, Queensland Museum Earthwatch team, 1-7 Nov 1981, RFPT, carded ex ethanol, in QM. OTHER MATERIAL. Bellenden Ker Range, 1km S cable tower 6, 17°16'S 145°53'E, 500m, EQM, 17-24 Oct 1981, 1 sub. ♂, 4 ♀, in 4 series; Bellenden

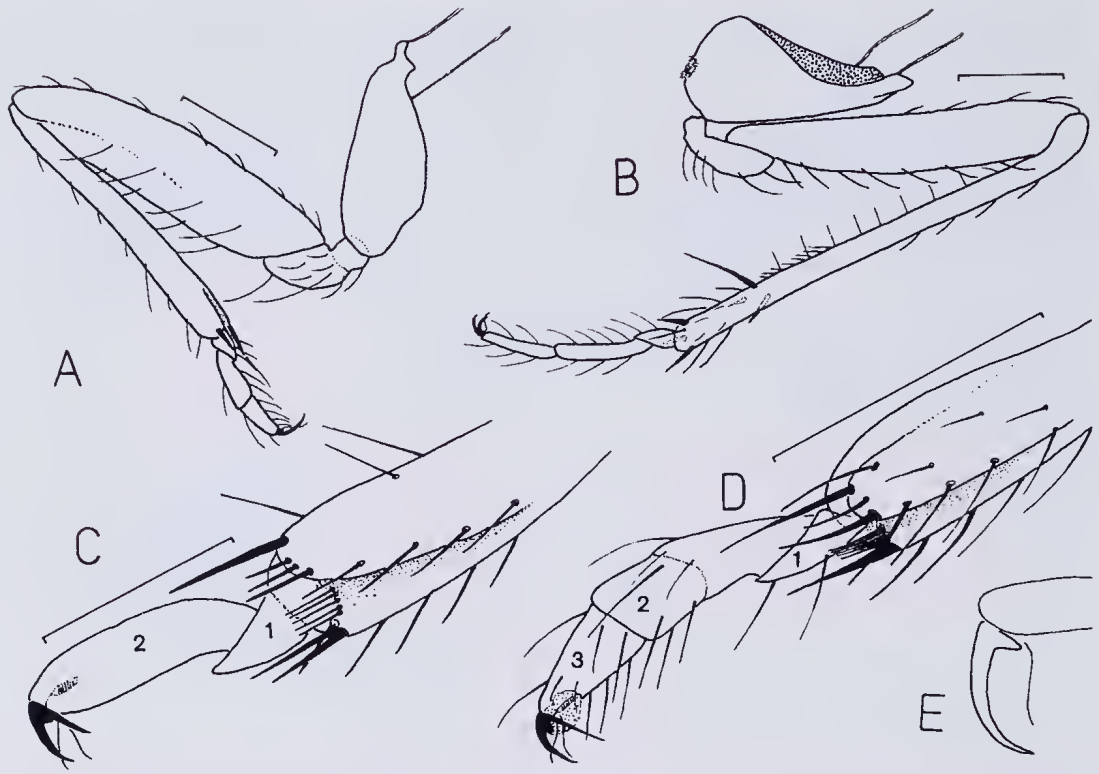

FIG. 12. A-B, *K. notipolysperes* submacropetrous ♂; A, mid leg, anterior; B, hind leg, posterior; C-D, *K. epicarsius*; C, ♀ foretarsus, anterior; D, same, ♂; E, hind claw, *K. sidereoriensis*.

Ker Range, 0.5km S cable tower 7, 500m, EQM, 1-7 Nov 1981, 1 ♀; in QM.

DESCRIPTION. *Submacropterous Male.* General colour brown, head paler. Vertex pit in dorsal view semicircular anteriorly, posterior wall formed by concave face of disc protrusion, in anterior view broadly and roundly V-shaped, ridge barely visible, no arch evident in disc protrusion, anterior margin not depressed, anterior margin with acutely defined rim, vertex not depresed anteriorly to pit, medial ridge of pit flush with rim of pit and confluent with anterior rim of pit.

Pronotal disc projecting into pit and flattening into horizontal apex with tiny notch embracing ridge, protrusion otherwise squarely truncate; disc conspicuously concave above pit, convex anteriorly and strongly decurved in lateral view, not concurvilinear with head profile; weakly convex posteriorly and concurvilinear with anterior profile; humeral angles tumid; lateral margins convergent in dorsal view, not dilate; posterior margin narrowly decurved. Metapleurae not prominent in dorsal view.

Forewings paler proximally, in repose forming pale transverse band on body; 2 free veins subapically.

T1 granulate (Fig. 15B). Posterior margin S6 simple. Disc of S7 with very weak impression submedially but no adjacent tumescence sublaterally on right, posterior margin weakly produced on right. Genital capsule with distinct tumescence on right posterior corner; left paramere 0.208mm. Conjunctival sclerites of aedeagus with short spinous process much shorter than basal plate (Fig. 18A). Vesica sinuous, not looped, with subapical tooth; vesica with subequal, cosinuate branch arising beyond midlength, branch apex simple.

Female. Venation brown, lighter towards costa; 2 cream, closed cells.

DISTRIBUTION. Known from 2 localities in rainforest at 500m associated with the Bellenden Ker Range cableway in Bellenden Ker - Bartle Frere Uplands region. Females from the

cableway base station at 100m might be this species or the widespread macropterous species *K. epicarsius*. The latter is known from the cableway base station.

NOTES. Macropterous male unknown. Collected in litter berlesates and pitfall traps in rain forest.

Kaimon plistonotius sp. nov.
(Figs 9A-C, 14J, 18C, Tables 2, 3)

ETYMOLOGY. Latinised Greek adjective meaning 'most southern' alluding to the distribution of this species.

MATERIAL. TYPES. Holotype: sub. ♂, Wilson Park, 3km ESE Lismore, 50m, NSW, Peck, 25 Aug 1982, dry RFB-SBP113S, carded ex ethanol, in ANIC. Paratypes: 7 sub. ♂ and 7 ♀ in vial, 1 ♀ carded, 1 sub. ♂ in 2 slides and vial, 1 ♀ in slide, as for holotype, in ANIC. OTHER MATERIAL. New England National Park, 1500m, NSW, Peck, 26 Aug 1982, 3 sub. ♂, 3 ♀.

DESCRIPTION. *Submacropterous Male.* General colour dark red-brown, posterior third disc lighter brown, venation brown but costa and claval marginal vein yellow-brown, vertex not yellow-brown medially. Curvature of frons not flattened, profile of frons merges gradually with vertex, vertex without pit or lobe but with minute, vestigial depression.

Pronotal disc slightly flattened anteromedially, anterior margin with vestigial medial emargination; disc straight in profile anteriorly and posteriorly but with change of plane; humeral angles not tumid; lateral margins parallel, not dilate; posterior margin narrowly deflexed full width. Metapleurae prominent in dorsal view.

Posteroventral macroseta on hind tibiae long (2.6 tibial diameters).

Forewings without pale band proximally, 1 free vein apically but two veins subapically, posterior vein coalseces with preceding vein.

T1 microgranulate. Posterior margin S6 simple. Right posterior angle S7 broadly and strongly projecting posteriorly, discs S5-7 with large, strongly depressed area submedially on right. Genital capsule with broad rounded tumescence on right posterior angle; left paramere 0.127mm. Conjunctival sclerites of aedeagus uncertain, probably with spinous process. Vesica forming single spiralled loop, apex simple, no branch.

Female. Posterior third disc lighter brown than remainder of body.

DISTRIBUTION. Known from 2 localities in northern New South Wales at 50 and 1500m. Two females from Barrington House, 40km NW Dungog, 400m not associated with males could belong to this species. Dungog is the southernmost locality for the genus in Australia.

NOTES. Macropterous male unknown.

Kaimon polysperes sp. nov.
(Figs 2C, 3I, 5I, 7I, 11E, 13A-B, 14L, 15G, 17A-C, Tables 2-3)

ETYMOLOGY. Greek adjective meaning 'widespread' alluding to the many regions in which this macropterous species occurs.

MATERIAL. TYPES. All in ANIC. Holotype: Sub ♂, 2.5km W by N Mt Baldy, 17°16'S 145°26'E, 1000m, Calder & Weir, 29 Mar 1984, ANIC948, carded. Paratypes: as for holotype, 3 mac. ♂, 20 sub. ♂ and 32 ♀ in ethanol, 1 sub. ♂, 2 ♀ and 1 mac. ♂ carded. OTHER MATERIAL. Three sub. ♂ and 3 ♀ were removed from the type series and sent to Australian Museum, Sydney for scanning electron micrography. Mine site, Mt Lewis via Julatten, A. Walford-Huggins, 8 Mar 1985, 7 sub. ♂, 1 nymph; Ravenshoe SF, Tully Falls Rd, A. Walford-Huggins, 10 Oct-15 Nov 1987, 1 mac. ♂; Birthday Ck, 6km NW by N Paluma, 18°59'S 140°10'E, Weir, 25 Sep 1980, 2 mac. ♂, 2 sub. ♂, 1 ♀; Tully Falls, A. Walford-Huggins, 4 Oct 1978, 2 mac. ♂; 1km S Mt Lewis, 950m, Calder & Weir, 28 Mar 1984, 11 sub. ♂, 23 ♀; Mt Windsor Tbld via Mt Carbine, 27 Dec 1984, A. Walford-Huggins, 1 ♀; Mt Lewis, 20km S Mossman, 1000m, Peck, 10 Jul 1982, 2 mac., 10 sub. ♂, 2 ♀; Topaz NP SE Malanda, 720m, Peck, 28 Jul 1982, 1 sub. ♂, 2 ♀; in ANIC. Mossman Bluff, 5-10km W Mossman, 250-1260m, MT/ANZSES, Jan 1988, Jan 1989, Dec 1989, Jan 1990, 16 mac. ♂, 1 ♀ in 11 series (of which 1 series sympatric with *K. epicarsius*); Windsor Tbld, 1225-1300m, E. Schmidt and ANZSES, 9 Jan 1989, 2 sub. ♂ in 2 series; 1.5km SW Mt Spurgeon via Mt Carbine, 1100m, MT/ANZSES, 21 Dec 1988-5 Jan 1989, 2 mac. ♂; 2km SW Mt Spurgeon via Mt Carbine, 1100m, MT/ANZSES, 20 Dec 1988-4 Jan 1989, 1 mac. ♂; Mt Fisher 7km SW Millaa Millaa, 1050-1100m, 27-29 Apr 1982, MYC, 1 mac. ♂ (in series with 2 sub. ♂ *K. athertonensis*); Mt Fisher (Kjellberg Rd), 17°32'S 145°33'E, 1100m, Monteith, 17 May 1995, 1 mac. ♂; Bluewater Range, 50km WNW Townsville, 700m, Monteith, Thompson & S. Hamlet, 5-9 Dec 1986, 6 mac. ♂; Birthday Ck, Paluma Dam Rd, 800m, 17 Nov 1990, Monteith & Seymour, 1 sub. ♂; Paluma Dam Rd, site 3, 800m, 17 Nov 1990-8 Dec 1990, Monteith & Seymour, 1 mac. ♂; Mt Halifax summit, 19°07'S 145°23'E, Cook, 21 Mar 1993 - 10 May 1993, 1 mac. ♂, 5 sub. ♂; Hughes Rd, Topaz, 17°26'S 145°42'E, 650m, Monteith & Breeden, Sep - Dec 1993, 2 sub. ♂, 1 ♀; Paluma Dam Rd, site 2, 720m, Monteith & Seymour, 17 Nov- 8 Dec 1990, 1 mac. ♂; Black Mtn Rd, Kuranda, 17°47'S 145°39'E, 360m, Monteith, 8 Jun 1980, 3 mac. ♂; Wallaman Falls via Ingham, 500m, 1 Oct 1980, Monteith, 1 mac. ♂; Wallaman Falls via Ingham, 500m, Monteith, 1 Oct 1980, 1 sub. ♂;

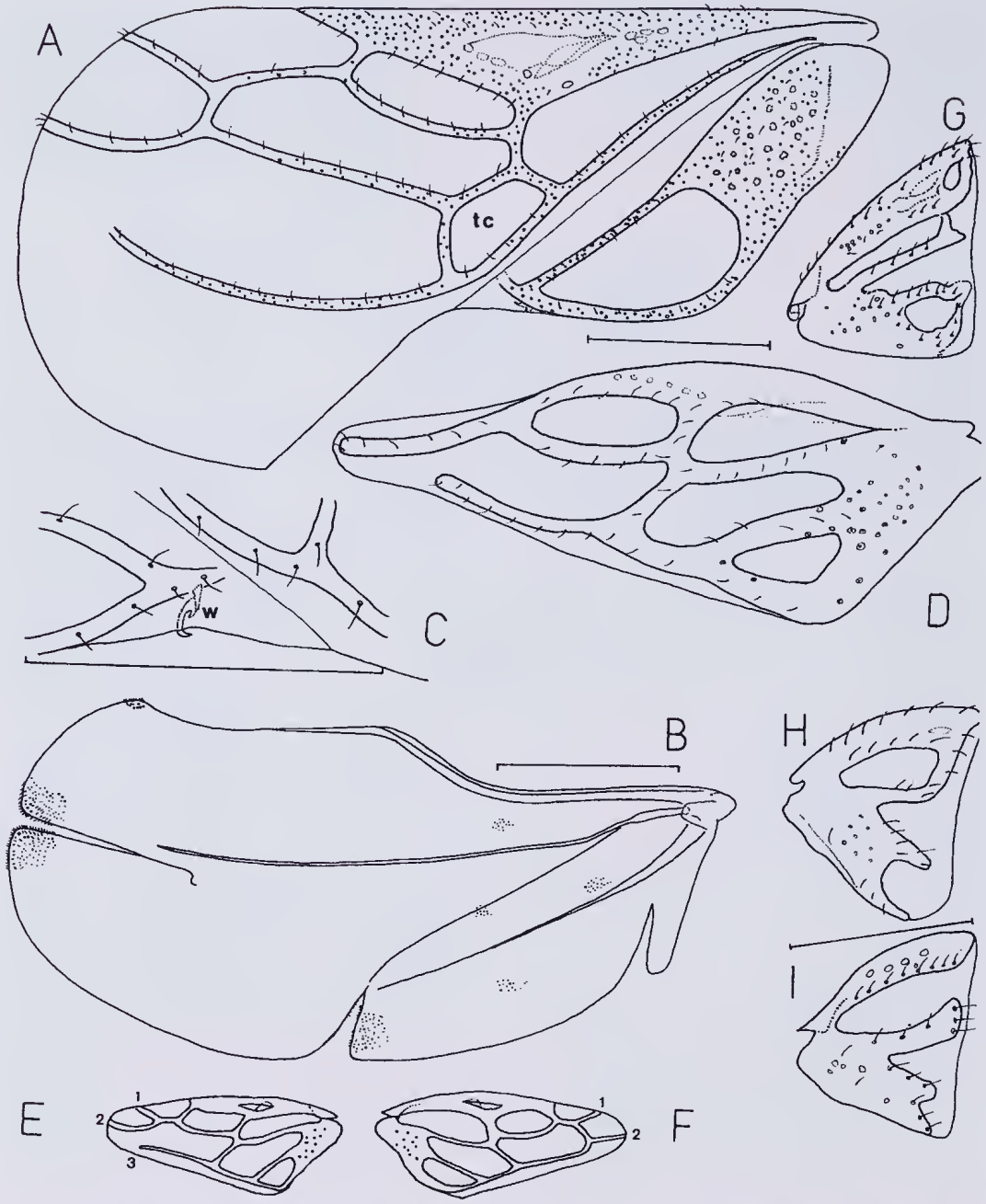

FIG. 13. Wings, dorsal views. A-B, macropterous ♂ *K. polysperes*; A, forewing; B, hind wing; C, undescribed ♂ ex Lamb Range, wing coupling on right claval apex; D-F, submacropterous ♂♂; D, *K. thortonensis*, left forewing; E-F, left and right forewings of one ♂ *K. epicarsius*; G, micropterous ♂, *K. micropterus*, right forewing; H-I, micropterous ♀, *K. epicarsius*, right forewings of two ♀♀ from one series. Scale lines 0.1mm; C, approximate scale; E-F unscaled sketches. tc=trapezpoidal cell; w=wing coupling; 1,2,3=apically free veins of forewing.

Windin Falls, NW of Mt Bartle-Frere, 580m, 9 Oct 1980, Monteith, 1 mac. ♂ (sympatric in series with 1 mac. ♂ *K. epicarsius*); Mt Lewis via Julatten, 16°35'S 145°12'E, Monteith, 12 Oct 1980, 1 sub. ♂; 2km N Mt Lewis via Julatten, 1000m, Monteith & Cook, 8 Sep 1981, 1 sub. ♂; Windsor Tbld, 28-35km NNW Mt Carbine, 900-1150m, MYC, 15-26 Apr 1982, 3 mac. ♂, 12 sub. ♂, 8 ♀ in 11 series; The Bluff, 11km W Mossman, 16°27'S 145°16'E, 950m, MY, 27 Apr 1983, 1 mac. ♂; Mt Fisher, 7km SW Millaa Millaa (Kjellberg Rd), 17°33'S 145°33'E, 1000m, MY, 3 May 1983, 1 sub. ♂, 3 ♀ in 2 series; 2.5km N Mt Lewis via Julatten, 16°34'S 145°16'E, 1040m, Yeates & Thompson, 3 Nov 1983, 1 sub. ♂, 1 ♀ in 2 series; 22km SW Mareeba, 17°07'S 145°36'E, 900m, Yeates & Thompson, 4 Nov 1983, 2 sub. ♂, 1 ♀; 21km S Atherton,17°27'S 145°28'E, 1040-1100m, 5 Nov 1983, Yeates & Thompson, 1 sub. ♂; Mt Fox Rd (Seaview Range), 18°50'S 145°50'E, 600m, MT, 15 Dec 1986, 2 sub. ♂ in 2 series; Broadwater Park via Ingham, 18°22'S 145°57'E, 60m, MT, 16 Dec 1986, 1 mac. ♂; Cardwell Range (Mt Macalister), 18°18'S 145°56'E, 1000m, MT, 20 Dec 1986, 1 sub. ♂; Cardwell Range (Upper Broadwater Valley), 18°18'S 145°56'E, 800m, MT, 13 Dec 1986, 1 mac. ♂, 1 ♀; Wallaman Falls Rd, 18°35'S 145°51'E, 600m, 14 Dec 1986, MT, 1 mac. ♂; Lamb Ra. 19km SE Mareeba, 17°06'S 145°34'E, 1200m, 3 Dec 1988, MT, 3 mac. ♂; Lambs Head, 10km W Edmonton, 17°02'S 145°38'E, 1200m, MT, 4 Dec 1988, 1 mac. ♂; Sluice Ck, 9km WSW Millaa Millaa, 17°33'S 145°33'E, 1150m, MT, 5 Dec 1988, 1 mac. ♂; Hugh Nelson Range, 2.5km S Crater NP, 17°17'S 145°28'E, 1100m, MT, 5 Dec 1988, 2 sub. ♂, 2 ♀; Hughes Rd, Topaz district, 17°26'S 145°42'E, 650m, 5 Dec 1983, 1 sub. ♂ (sympatric in series with 1 sub. ♂, 3 ♀ *K. epicarsius*); Mt Fisher (Kjellberg), 17°32'S 145°33'E, 1100m, Monteith, 17 May 1995, 1 mac. ♂ (sympatric in series with 1 sub. ♂ and 7 ♀ *K. athertonensis*); in QM.

DESCRIPTION. *Submacropterous Male.* General colour dark reddish brown to brown, vertex concolourous. Vertex pit in dorsal view pear-shaped (broader anteriorly), posterior margin formed by incised anteromedial margin of disc, U- to V-shaped in anterior view, ridge and embracing arch visible, anterior margin not depressed, with acutely defined rim, no depression anterior to pit but curvature of frons flattened, posterior apex of pear-shaped pit formed between points of incised apex of discal protrusion, medial ridge of pit more or less flush with rim of pit and confluent with anterior rim of pit, inner rim confluent with points of discal protrusion, outer rim superior to intruding points of disc.

Pronotal disc closely embracing ridge of pit in anterior and dorsal views, disc weakly flattened above pit, steeply inclined into pit but lacking any horizontal portion in pit, in dorsal view forming notched apex to pit rather than arc-shaped posterior wall, line between points of protruding disc incised in views dorsal to both disc and body axis; disc convex anteriorly and strongly decurved in lateral view, not concurilinear with head profile; weakly convex posteriorly, almost flat, slight discontinuity with anterior profile; humeral angles tumid and dilate (Figs 3I, 5I); lateral margins weakly convergent in dorsal view, dilate; posterior margin dilate near humeral angles. Metapleurae not prominent in dorsal view.

Forewings usually paler proximally, proximal 3 cells cream, proximal veins light brown, distal cells sooty brown, distal veins dark brown; 2-3 free veins subapically.

T1 carinulae in form of vestigial triangles, not clearly carinulate or granulate. Posterior margin S6 simple (Fig. 14L). Disc of S7 with weak impression submedially on right and weak tumescence sublaterally on right, latter not prominent and not adjacent to posterior margin, posterior margin weakly projecting on right. Genital capsule with distinct and acutely rounded tumescence on right posterior angle (Fig 14L); left paramere 0.204mm. Conjunctival sclerites of aedeagus possibly with short, spinous process (Fig. 17B). Vesica incomplete, biramous loop with subequal concurvilinear branch, vesical apex with subapical tooth; branch apex simple.

Macropterous Male. Length overall 1.12mm. Ridge of pit flush and confluent with rim of pit, lateral margins of disc dilate, humeral angles tumid and dilate as in submacropter; T1 carinulate; genital capsule with tumescence on right corner as in submacropter.

Female. Colour generally brown, forewing veins brown, 1 cream, closed cell.

DISTRIBUTION. *K. polysperes* occurs in 9 regions (Table 4) at 600-1200m and 1 site (Broadwater Park via Ingham) at 60m. It is 1 of 2 widespread species in the Wet Tropics, the other being *K. epicarsius*. Both are macropterous. It is sympatric with *K. epicarsius* at 4 localities (Mossman Bluff 600m and 760m, Windin Falls, 580m and Topaz District, 650 m), with *K. athertonensis* on Mt Fisher above 1050m and with *K. leeiensis* at Wallaman Falls at 600m.

NOTES. *K. polysperes* is distinguished by dilation of the humeral angles and a medial ridge in the vertex pit that is flush and confluent with the rim (Fig. 2C). A macropterous male from Baldy Mountain has an aberrant cross vein (1v-2v) at midlength on the clavus of the right but not left forewing. The pale band on the forewing was illdefined in some males from Mt Halifax.

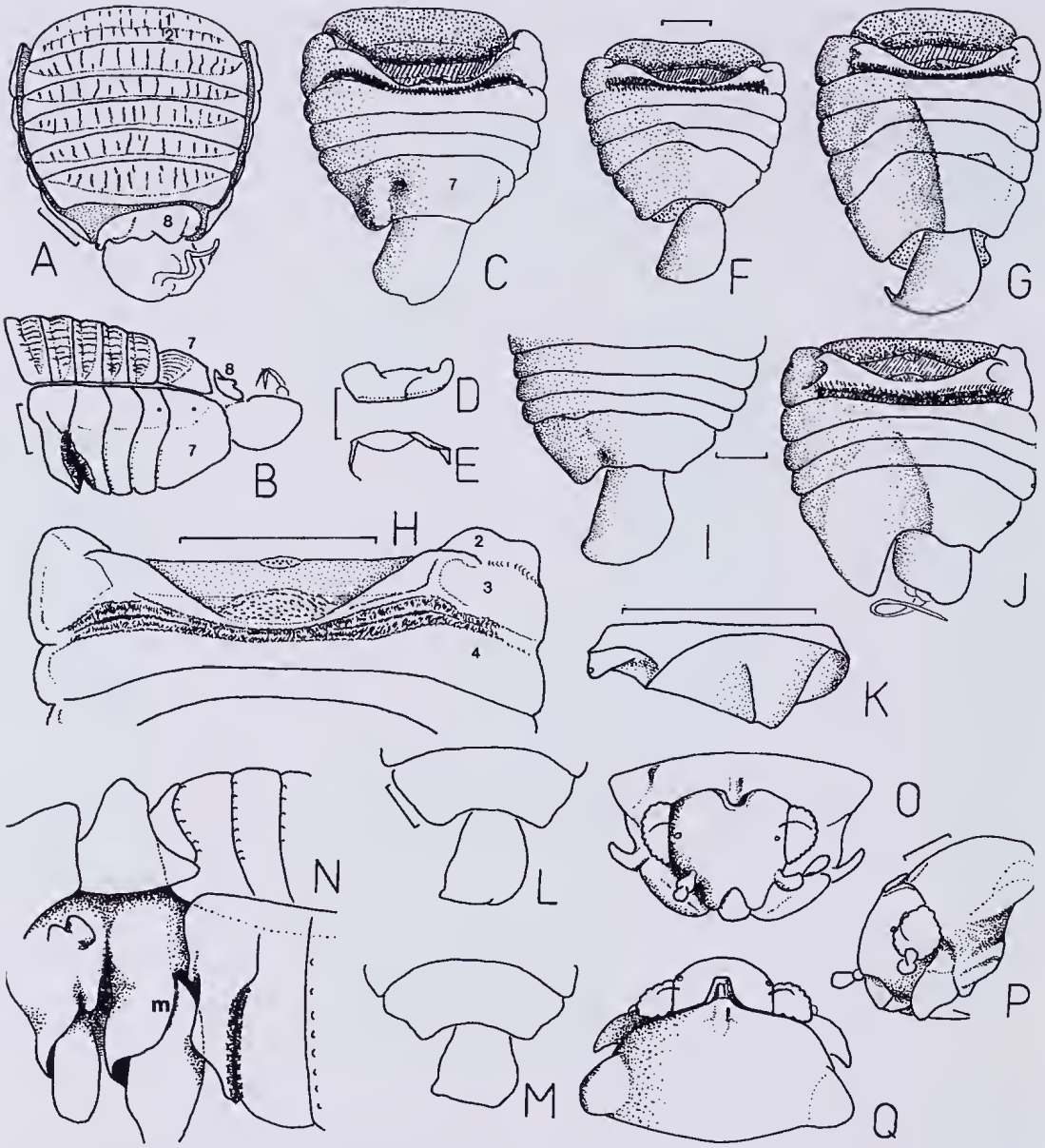

FIG. 14. A-M, ♂ abdomen. A-E, *K. epicarsius*; A, dorsal; B, lateral; C, ventral; D, T8, dorsal; E, same, anterior; F, *K. sidereoriensis*, ventral; G, *K. eungellanus*, ventral; H, same, S2-S5; I, *K. finniganensis*, ventral; J, *K. plistonotius*, ventral; K, *K. mesambrinus*, T8, dorsal; L, *K. polysperes*, caudum, ventral;m, *K. allomelanoriensis*, caudum, ventral; N, *K. kroombitensis* ♀, pterothorax and anterior abdomen, left lateral; O-Q, macropterous ♂, anterior half, undescribed species, Mt Tozer area; O, anterior; P, lateral; Q, dorsal. Scale lines 0.1mm; N unscaled sketch. C, F, G, J underside of T1-2 stippled, hyaline parts S2-3 hatched; H, hyaline parts S2-3 stippled. m=metepisternum where it abuts abdominal carinae; 2, 3, 4, 7, 8=sterna or terga.

Collected in litter, moss and stick brushing berlesates, pitfall traps and flight intercept traps in heath, open forest and rain forest.

Kaimon sidereoriensis sp. nov.
(Figs 2B, 3F, 5F, 7F, 14F, 15A, 19A-C,L, Tables 2-3)

ETYMOLOGY. Latinised Greek meaning 'of iron mountain', alluding to the Iron Range distribution.

MATERIAL. TYPES. All in QM. Holotype. T.108854: sub. ♂, West Claudie R., Iron Range, 12°45'S 143°14'E, 50m, Monteith, 9 Dec 1985, RFSLB-QM698, carded. Paratypes: as for holotype, 1 mac. ♂ carded, 1 ♀ carded, 9 ♀ (and 1 nymph) in ethanol. OTHER MATERIAL. 3-11km ENE Mt Tozer, 12°43'-44'S 143°14'-18'E, Weir, 1-16 Jul 1986, 4 mac. ♂, 8 sub. ♂, 11 ♀, 1 nymph in 5 series (of which 1 serics sympatric with the undescribed species mentioned below); in ANIC. West Claudie R., Iron Range, 12°43'-45'S 143°14'E, 50m, Monteith & Cook, 3-10 Dec 1985, 5 mac. ♂, 8 sub. ♂, 19 ♀ in 7 series; in QM.

DESCRIPTION. *Submacropterous Male.* General colour light brown with paler yellowish brown areas. Vertex pit circular in dorsal view with curved, posterior margin formed by excavate anteromedial protrusion of disc in dorsal view, anterior margin squared U-shape in anterior view, anterior margin indistinct, vertex faintly and broadly impressed anteriorly to pit, medial ridge of pit recessed and disjunct with anterior rim of pit.

Pronotal disc embracing ridge in vertex pit in anterior view but not projecting into pit in dorsal view, points of excavate anteromedial disc margin rounded and confluent with vertex pit rim in anterodorsal view, line between points concave in dorsal views perpendicular to disc and perpendicular to whole body axis (latter not true for mac. male), hence disc broadly but briefly sulcatc abovc vertex pit; convex anteriorly and strongly decurvcd in lateral view, not concurvilinear with vertex profile; convex posteriorly and concurvilinear with profile of anterior disc; humeral angles not tumid; lateral margins weakly convergent in dorsal view, not dilate. Metapleurae not prominent in dorsal view.

Forewings pale proximally, in repose forming pale transverse band on body (non costal veins brown proximally and distally, light brown medially, cells cream proximally, sooty brown distally).

T1 carinulate (Fig. 15A). Posterior margins S5 and S6 each with slight asymmetric projection left of midline indicating path of faint longitudal ridge running from S5 to S7 and forming medial margin of broad depressed area of right side of S7 disc (Fig. 14F). S7 without adjoining tumescence and depression on right side near posterior margin; posterior margin of S7 moderately produced. Genital capsule simple, right posterior corner without distinct tumescence; left paramere 0.085-0.094mm. Conjunctival sclerites of aedeagus lacking spinous process. Vesica incomplete spiralled loop, vcsical apex minutely incised, with short branch arising subapically.

Macropterous Male. Length overall 0.88mm (n=5). Lcft paramere 0.102mm (from type locality but not type series).

Female. General colour light brown with paler yellow-brown patches on head, anteromedial disc and scutellum, forewings concolourous with body except for 1 cream, closed cell.

DISTRIBUTION. Several sites in the Iron Range region in Cape York Peninsula at 50m and perhaps higher near Mt Tozer. *K. sidereoriensis* is sympatric with an undescribed, macropterous species, noted below, at 9km ENE of Mt Tozer.

NOTES. The number of free veins subapically on the fore wing varied from 2 to 3 between right and lcft of one suFrombmacropterous male. This was because vein 1 was absent on right side whereas in *K. epicarsius* the variation in number of free veins was because veins 2 and 3 anastomosed on right side but not on left (Fig. 13E-F). Collected by litter and palm berlesates and flight intercept traps from rain forest.

Kaimon thorntonensis sp. nov.
(Figs 3C, 5C, 7C, 10D, Tables 2-3)

ETYMOLOGY. From the Thornton Uplands.

MATERIAL. TYPES. All in QM. Holotype T.108851: sub. ♂, Thornton Peak via Daintree, 1150m, Monteith & Cook, 20-22 Sep 1981, RFSLMB-QM301. Paratype: 1 sub. ♂, carded (right forewing missing), as for holotype. OTHER MATERIAL. All in QM. Mt Sorrow summit, C. Tribulation, 16°.08S 145°.26E, 800m, Monteith, 15 and 19 Oct 1980, 3 sub. ♂, 7 ♀ in 3 series; 3.5-5km W C. Tribulation (sites 7, 8, 9 and 10) 16°05'S 145°26'-27'E, 680-780m, Sep-Oct 1982 and Jan-Apr 1983, MYT, 3 sub. ♂, 10 ♀ in 8 series; Roaring Meg Ck, 6km W C. Tribulation, 16°05'S 145°24'E, 710m, MYT, 5 Oct 1982, 2 ♀; Mt Hemmant, 6km SW C. Tribulation, 16°07'S 145°25'E, 880m, Monteith & Cook, 25 Apr 1983, 6 sub. ♂, 15 ♀ in 3 series.

DESCRIPTION. *Submacropterous Male.* General colour dark brown, vertex concolourous, posterior quarter of pronotal disc sometimes lighter brown. Rim of vertex pit circular with curved posterior margin formed by excavate anteromedial margin of disc in dorsal view; rim ill-defined, roundly V-shaped with minutely

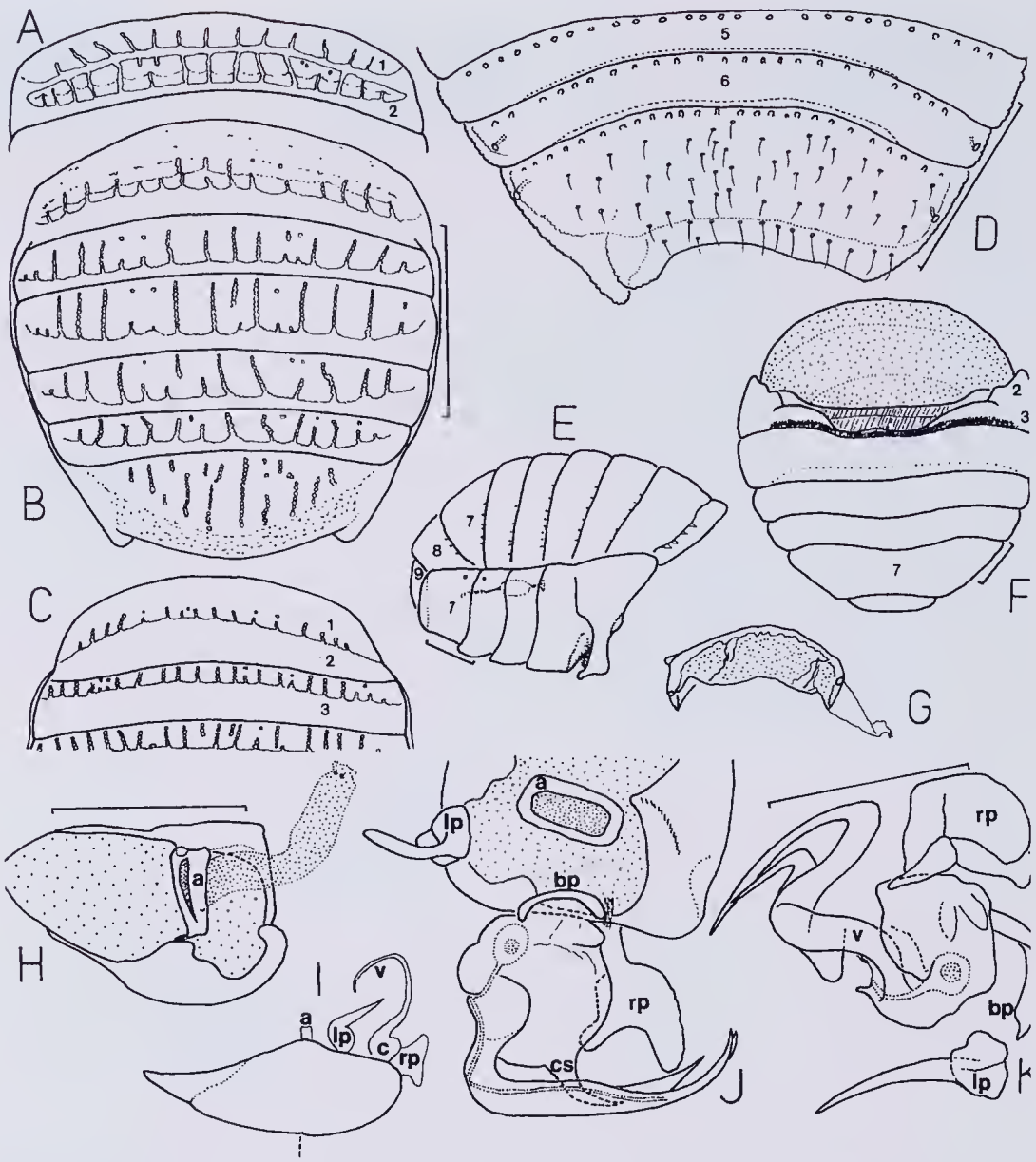

FIG. 15. A-C, abdominal terga, dorsal; A, *K. sidereoriensis*, T1+T2; B, *K. pismaensis*, T1-T7; C, *K. micropterus*, T1-4; D-F, *K. epicarsius*; D, ♂ S5-S7, ventral; E, ♀ abdomen, ventral; F, same, lateral; G, *K. polysperes*, T8, dorsal, compresed on slide; H-I, *K. epicarsius*; H, ♂ genital capsule with anophore and anal tube, dorsal; I, ♂ genital capsule with anophore and genitalia, lateral (dashed line indicates position to which capsule is retracted and hyaline); J, *K. finniganensis*, posterior half of ♂ genital capsule with anophore and dissected genitalia, dorsal; *K*, *K. micropterus*, aedeagus and parameres, dissected. Scale lines 0.1mm. a=anophore; bp=basal plate; c=conjunctival sclerites; cs=conjunctival spine; lp=left paramere; rp=right paramere; v=vesica; 1, 2, 3, 5, 6, 7, 8, 9=sterna or terga

notched apex in anterior view, rim impressed, not flush with vertex, with medial notch merging with narrow, well defined gutter in vertex; gutter

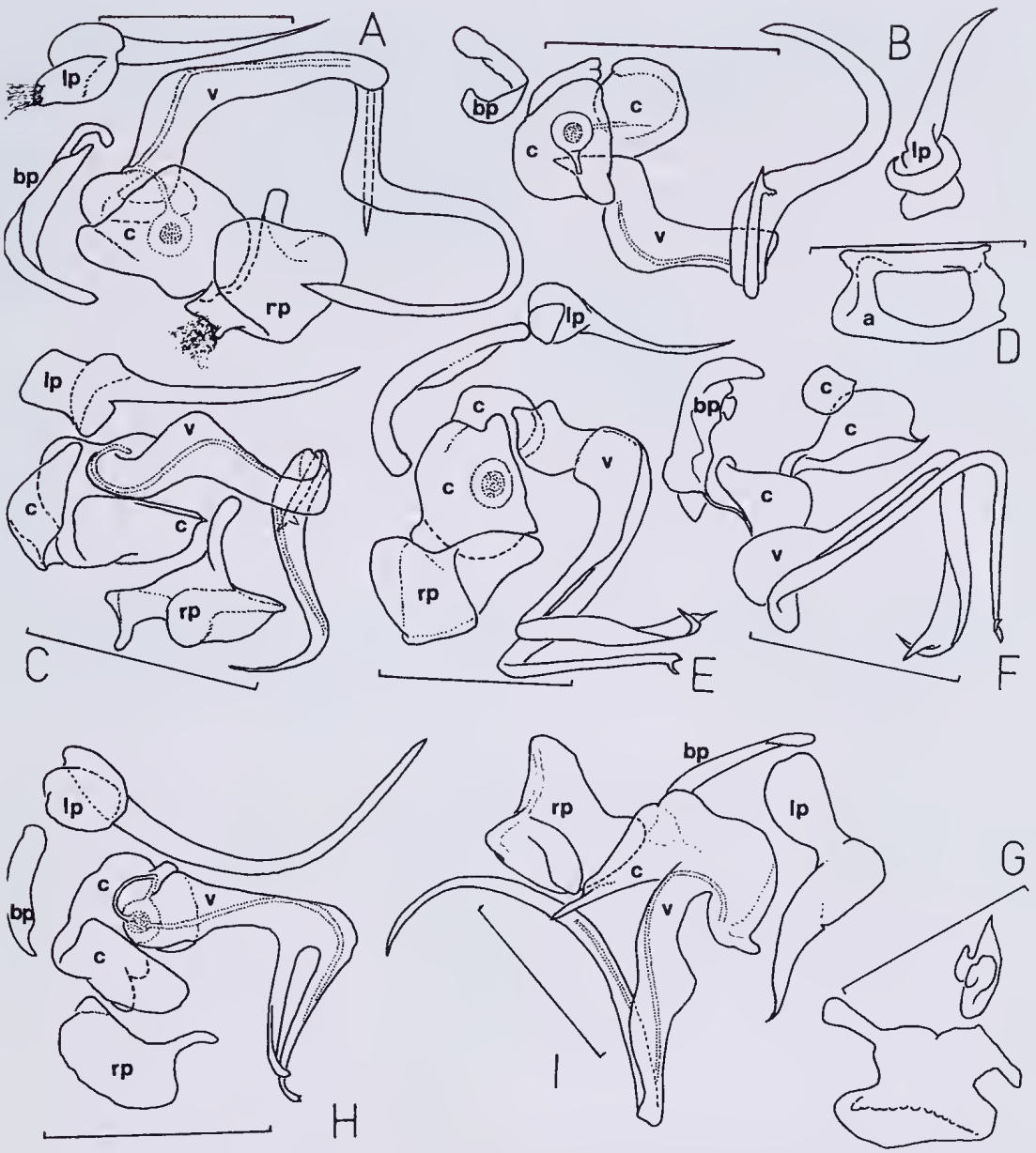

FIG. 16. A-D, *K. epicarsius*; A-C, aedeagus with or without parameres from three ♂♂; D, anophore; E-G, two ♂♂ of *K. thorntonensis*; E, aedeagus with parameres; F, aedeagus without parameres; G, right paramere and unknown sclerite; H, *K. conwayensis*, aedeagus with parameres; I, *K. mesambrinus*, same. Scale lines 0.1mm. a=anophore; bp=basal plate; c=conjunctival sclerite/s; lp=left paramere; rp=right paramere; v=vesica.

diminishing toward frons; medial ridge of pit recessed and disjunct from anterior rim of pit.

Anteromedial margin of pronotal disc forming posterior margin of vertex pit in dorsal view, points of excavate margin confluent with depressed vertex pit rim, embracing pit ridge in anterior but not dorsal view; anteromedial disc flat (not convex), perhaps weakly impressed immediately above vertex pit; disc convex anteriorly and decurved in lateral view,

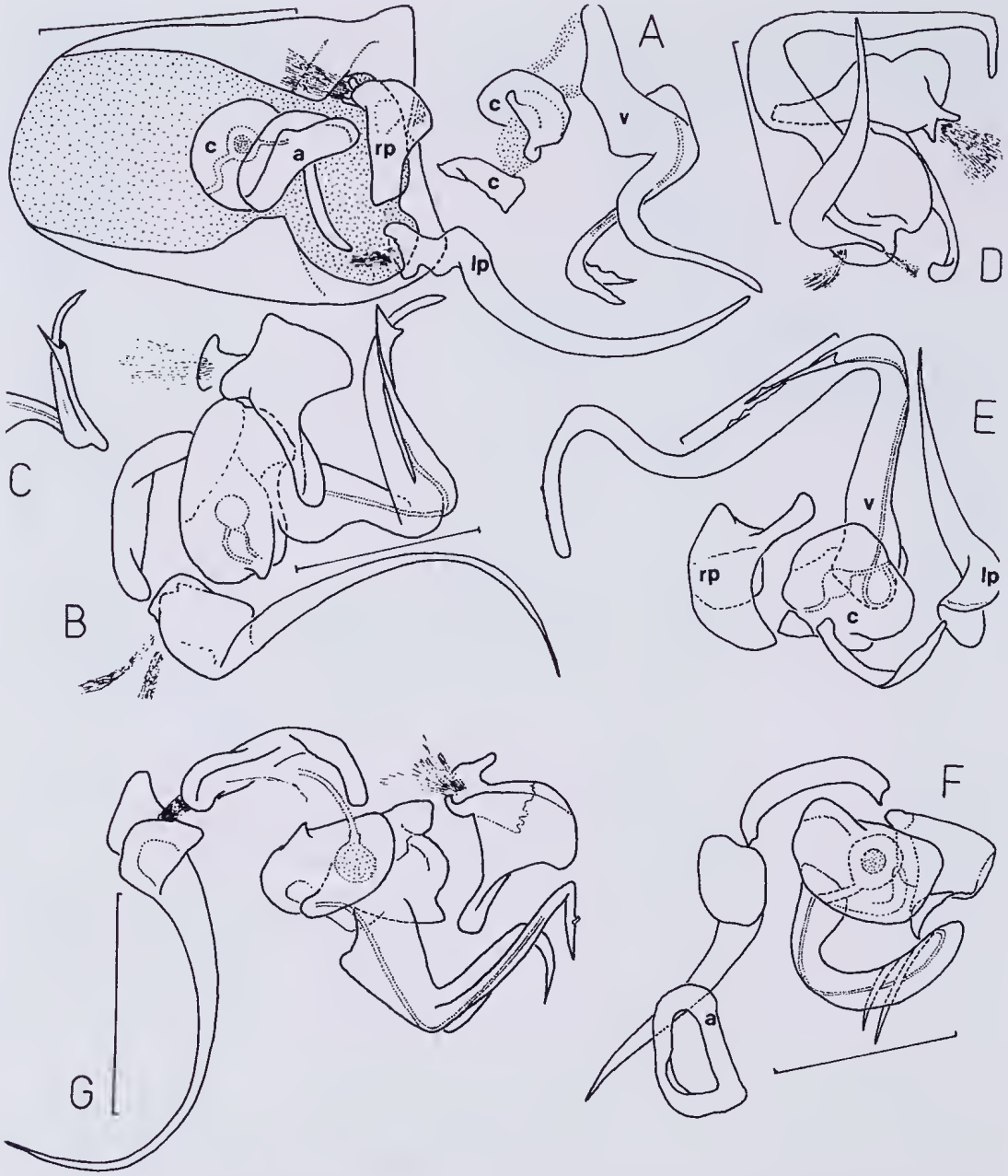

FIG. 17. A-C, *K. polysperes*; A, genital capsule dissected, dorsal; B, aedeagus and parameres, second ♂; C, detail of vesical apex from third ♂; D-G, aedeagus, basal plate and parameres; D, *K. eungellanus*; E, *K. ancylonesioticus*; F, *K. allonesioticus*; G, *K. athertonensis*. Scale lines 0.1mm. a=anophore; bp=basal plate; c=conjunctival sclerite/s; lp=left paramere; rp=right paramere; v=vesica.

concurvilinear with vertex, disc weakly convex posteriorly and smoothly continuous with anterior area in profile; lateral margins convergent anteriorly with anterior angles truncate, parallel medially but swollen posteriorly by weakly tumid humeral angles in

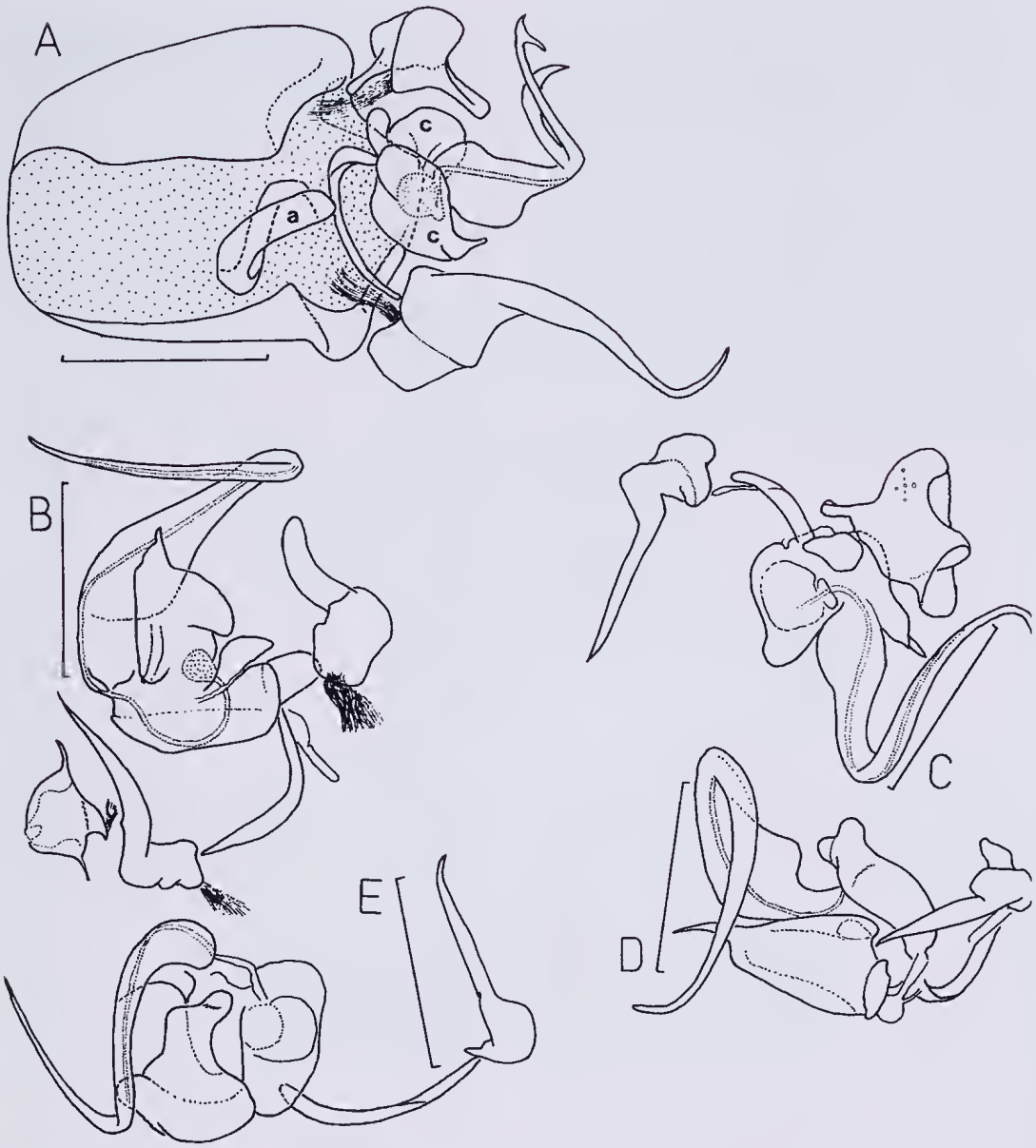

FIG. 18. A, *K. pismaensis*, genital capsule dissected, dorsal; B-E, aedeagus, basal plate and parameres; B, *K. kroombitensis*; C, *K. alleungellanus*; D, *K. byfieldensis* without right paramere; E, *K. plistonotius*;. Scale lines 0.1mm. a=anophore; c=conjunctival sclerite/s.

dorsal view; pronotal disc marginally wider near posterior margin in dorsal view; lateral margins of disc dilate; pronotal muscle scars depressed. Metapleurae prominent in dorsal view.

Forewings not paler proximally, 2 free veins subapically.

T1 granulate. Posterior margin S6 with weak asymmetric projection right of midline (like *K. finniganensis*, Fig. 14I); S7 lacking contiguous depression and tumescence on right, posterior margin weakly produced on right. Genital capsule without tumescence at right posterior angle; left paramere 0.147-0.159mm.

Conjunctival sclerites of aedeagus with short spinous process (Fig. 16F); vesica and concurved branch forming incomplete loop, vesical apex with small, recurved process; vesica with long, subequal branch, branch apex minutely bifid or trifid.

Female. Wings concolourous with body, cells not pale. Spermatheca globular.

DISTRIBUTION. Several sites on Thornton Peak and the Mt Hemmant-Mt Sorrow complex, but not the McDowall Range where *K. macdowallensis* occurs, in the Thornton Uplands region at 680-1150m.

NOTES. Macropterous male unknown. Males from sites 3-6km west of Cape Tribulation have slightly more convexity on anterior disc profile. Two females from west of Cape Tribulation are reddish brown like *K. epicarsius* and *K. melanoriensis*, rather than brown, but their wing pads are concolourous with the body. All series were collected by rain forest sieved litter berlesates except the type series which was from a litter and moss berlesate. See also *K. carbinensis* notes.

Kaimon webbensis sp. nov.
(Figs 4C, 6C, 8C, Tables 2, 3)

ETYMOLOGY. From the Mt Webb region.

MATERIAL. HOLOTYPE: sub. ♂, Mt Webb NP, 15°04'S 145°07'E, I.D. Naumann, 27-30 Apr 1981, yellow pan trap, carded ex ethanol. OTHER MATERIAL. Mt Webb NP, 15°04'S 145°07'E, Calder & J. Feehan, 27-30 Apr 1981, 2 ♀ in 2 series; in ANIC

DESCRIPTION. *Submacropterous Male*. General colour brown, vertex rim darker. Vertex pit in dorsal view square to trapezoidal, posterior wall formed by emarginate margin of protruding disc; in anterior view square, ridge and arch in disc embracing ridge barely visible, anterior margin weakly raised (Fig. 6C), with acutely defined rim, vertex not depressed anteriorly to pit, medial ridge of pit recessed and disjunct from anterior rim of pit; curvature of frons weakly flattened.

Proepimeral shelves very wide, posterior angle in dorsal view rectangular not acute or absent. Pronotal disc in dorsal view barely and loosely embracing depressed ridge of pit, points of excavate anteromedial margin of disc projecting into pit posterolaterally and inferiorly to outer rim of vertex pit, line between points concave in dorsal views perpendicular to disc and whole body axis; disc briefly sulcate above pit; convex anteriorly and weakly decurved in lateral view, concurvilinear with head profile; flat posteriorly and colinear with anterior profile; lateral margins clearly convergent in dorsal view, not dilate anteriorly but overhanging posteriorly (Fig. 6C), humeral angles weakly tumid; posterior margin of disc emarginate. Metapleurae prominent and sharing prominent angulate profile of propleural shelves in anterodorsal view.

Forewings not paler proximally; 2 free veins subapically.

T1 carinulation unknown. Posterior margin S6 simple. Disc of S7 with faint impression submedially and distinct tumescence sublaterally on right, latter near posterior margin, posterior margin weakly projecting on right. Genital capsule without tumescence on right posterior corner. Left paramere, conjunctival sclerites of aedeagus, vesica and branch unknown.

Female. Veins brown, 1 cream, closed cell.

DISTRIBUTION. One rainforest locality at unknown elevation in Mt Webb Region. The other species in this region (Table 4) is the micropterous *K. micropterus* described from a locality 30km to the south but also known in another region.

NOTES. Macropterous male unknown. No slides were prepared for this description because only 1 male is known. The emarginate posterior margin of the pronotal disc is distinctive. Collected in litter berlesates from rainforest and a yellow pan trap.

Undescribed species

No submacropterous males were available for a species (Fig. 14O-Q) from the Iron Range region. Three macropterous males of this undescribed species were sympatric with *K. sidereoriensis* in a series from 9km ENE Mt Tozer (berlesate ANIC1058). It is notable for its proepimeral shelves which project acutely at their posterior angles rather than tapering or turning squarely and the posterior margin of S6 has a digitiform ledge submedially to the right overlying S7. The vertex pit is squarish in dorsal view and its anterior margin acute and slightly raised. The medial ridge is recessed and disjunct from anterior rim of pit. The protrusion of the pronotal disc does not embrace the medial ridge, its apex is squarely truncate and without points. The disc is convex adjacent to vertex pit. In profile it is convex anteriorly and strongly decurved; weakly convex posteriorly and

FIG. 19. A-C, *K. sidereoriensis*; A, aedeagus; B, aedeagus, basal plate and parameres, second ♂; C, vesical apex, second ♂; D, *K. allomelanoriensis*, aedeagus, basal plate and parameres; E, *K. notipolysperes*, genital capsule dissected, ventral; F-G, *K. micropterus*, ♀ terminalia; F, left lateral; G, right dorsolateral; H, *K. mesambrinus*, ♀ terminalia compressed on slide, dorsal; I, *K. ancylonesioticus*, ♀ terminalia, left lateral; J-L, spermathecae; J, *K. finniganensis*; K, *K. athertonensis*; L, *K. sidereoriensis*. Scale lines 0.1mm; F-L sketches not to scale or roughly so. bp=basal plate; c=conjunctival sclerite/s; g=anterior gonapophysis lp=left paramere; rp=right paramere; 7=sternum 7; 8, 9= terga 8 and 9.

coplanar with the anterior section. The humeral angles are tumid. The lateral margins are strongly convergent. They are dilate posteriorly but not anteriorly. T1 is granulate. The left paramere is short, 0.090mm. The genital capsule lacks a tumescence on the right posterior corner.

Another undescribed species was represented by one macropterous male from Wallaman Falls Road and is noted in the description of *K. leeiensis*.

INDETERMINATE FEMALES. Beside those mentioned above indeterminate females were seen from the following localities: 2.5km SW Mt Hartley via Cooktown; Noah Head via Cape Tribulation, 40m; Davies Creek Road, 750m; 40km W Ingham, near Wallaman Falls, 600m; Cardwell Range, Upper Broadwater Ck Valley, 750m; Kirrama Range via Kennedy, 500m; Malanda Falls, 750m; 2km SE Mt Spurgeon via Mt Carbine, 1100m; Birthday Ck, Mt Spec, 850m and Paluma Township.

DISCUSSION

DISTRIBUTION. Regional diversity is summarised in Table 4. This analysis suggests that macropters do not exist in most species. The two most widespread species, *K. epicarsius* and *K. polysperes* are two of four described species for which macropters are known (another two macropterous species are not described but their distributions have been noted above). The third macropterous described species is *K. notipolysperes* from a dozen localities at all altitudes in south-eastern Queensland and adjacent New South Wales. Perhaps the fourth, *K. sidereoriensis* from Iron Range will eventually prove to be more widespread in Cape York Peninsula. All the other described species, which all have submacropterous males and micropterous females occur in only one region. One exception is *K. micropterus*. It has a micropterous male and occurs in two disjunct regions (Mt Webb and near Carbine Uplands).

SYMPATRIC SPECIES. In many instances sympatric species include a macropterous and a non macropterous species (Table 4). If the widespread macropterous species are ignored then the most diverse region is Central Queensland around Eugella with three endemic species although this region could also be regarded as three regions (Mt Dryander, Conway Range and Eungella). Another possible exception is *K. ancylonesioticus* which may occur in Elliot Uplands and Hinchinbrook Island regions.

In *Kaimon* females of all species and males of many species are flightless whereas in *Ogeria* some males and females of at least some species appear capable of flight. In *Pachyplagia* all males and females are macropterous.

TABLE 4. Number of described *Kaimon* species per rainforest region including the four macropterous species of which *K. epicarsius* (A) and *K. polysperes* (B) are the most widespread. *K. sidereoriensis* is C and *K. notipolysperes* is D. WT, Wet Tropics Zone of North Queensland. The term Uplands is used here in regional names following Yeates et al. (2002) but some localities for *Kaimon* are lowland. Based on 167 series of specimens containing 80 macropterous and 350 submacropterous males. [1], an undescribed macropterous species occurs in the Iron Range region in addition to the described macropterous species that is tabulated. Another possibly occurs in Lee Uplands; [2], *K. micropterus* is the non endemic and non macropterous species in these two regions; [3], 1 undescribed species in or near *K. ancylonesioticus* of Hinchinbrook Island.

Region	No. of species, first value includes second	Including the macropterous species
Northern Territory	1 species, 1 endemic	
Iron Range, northern Queensland, north of WT	1 species, 1 endemic [1]	C
Mt Webb, northern Queensland, north of WT	2 species, 1 endemic [2]	
Finnigan Uplands, WT	3 species, 1 endemic	A & B
Thornton Uplands, WT	3 species, 2 endemics	A
Windsor Uplands, WT	1 species, 0 endemic	B
Carbine Uplands and Bakers Blue Mtn, WT	4 species, 1 endemic [2]	A & B
Black Mtn Corridor, WT	4 species, 2 endemics	A & B
Lamb Uplands, WT	2 species, 1 endemic	A
Malbon-Thompson Uplands, WT	1 species, 0 endemic	A
Bellenden Ker – Bartle Frere Uplands, WT	2 species, 1 endemic	A
Atherton Uplands, WT	3 species, 1 endemic	A & B
Kirrama Uplands, WT	1 species, 0 endemic	B
Hinchinbrook Island	2 species, 2 endemics	
Lee Uplands, WT	2 species, 1 endemic [1]	B
Spec Uplands, WT	1 species, 0 endemic	B
Halifax Uplands, WT	1 species, 0 endemic	B
Elliot Uplands, WT	0 species [3]	
Mt Dryander/Conway Range/Eungella, central Queensland	3 species, 3 endemics	
Byfield, central Queensland	1 species, 1 endemic	
Kroombit/Bulburin, central Queensland	2 species, 2 endemics	
Southeastern Queensland	2 species, 2 endemics	D
New South Wales	1 species, 1 endemic	

NON AUSTRALIAN DISTRIBUTION. One female, Indonesia, Sulawesi Utara, Dumoga-Bone NP, March 1985, Plot A, 200m, lowland forest, Royal Entomological Society of London, Project Wallace, BM 1985-10. One submacropterous male, Solomon Islands, Kolombangara, N of Kuzi, 3000 feet, 4 Sep 1965, ground moss, moss forest 631-640, P.N. Lawrence, Royal Society expedition, BM1966-1.

ACKNOWLEDGEMENTS

I thank the curators G.B. Monteith at Queensland Museum and T. Weir at Australian National Insect Collection for loaning material and the many collectors named above.

LITERATURE CITED

DISTANT, W.L. 1913. Rhynchota (from the Seychelles). Part 1: Suborder Heteroptera. Transactions of the Linnean Society of London, Series 2, Zoology 16: 169-173.

HILL, L. 1984. New genera of Hypselosomatinae (Heteroptera: Schizopteridae) from Australia. Australian Journal of Zoology (Supplementary Series) 103: 1-55.

1990a. A revision of Australian *Pachyplagia* Gross (Heteroptera: Schizopteridae). Invertebrate Taxonomy 3: 605-617.

1990b. Australian *Ogeria* Distant (Heteroptera: Schizopteridae). Invertebrate Taxonomy 4: 697-720.

1992. A revision of *Pachyplagioides* Gross (Heteroptera: Schizopteridae). Invertebrate Taxonomy 6: 245-260.

EMSLEY, M.G. 1969. The Schizopteridae (Hemiptera: Heteroptera) with the description of new species from Trinidad. Memoirs of the American Entomological Society 25: 1-154.

KELLEN, W.R. 1961. A new species of *Ogeria* from the South Pacific. Proceedings of the Entomological Society of Washington 63: 17-20.

MONTEITH, G.B. 1997. Revision of the Australian flat bugs of the subfamily Mezirinae (Insecta: Hemiptera: Aradidae). Memoirs of the Queensland Museum 41: 1-169.

REN, S. 1991. New genus and new species of Chinese Schizopteridae (Hemiptera: Heteroptera). Acta Entomologica Sinica 34: 68-73.

SCHUH, R.T. & SLATER, J.A. 1995. True Bbgs of the World (Hemiptera: Heteroptera): classification and natural history. (Cornell University Press: Ithaca)

ŠTYS, P. 1969. On the morphology of the labrum in Heteroptera. Acta Entomologica Bohemoslovakia 66: 150-158.

1974. *Semangananus mirus* gen. n., sp. n. from Celebes – a bug with accessory male genitalia (Heteroptera: Schizopteridae). Acta Entomologica Bohemoslovakia 71: 382-397.

1982. A new Oriental genus of Ceratocombidae and higher classification of the family (Heteroptera). Acta Entomologica Bohemoslovakia 79: 354-376.

1990. Enicocephalomorphan and dipsocoromorphan fauna of W. Palearctic (Heteroptera): composition, distribution and biology. Scopolia Supplementum 1: 3-15.

YEATES, D.K., BOUCHARD, P. & MONTEITH, G.B. 2002. Patterns and levels of endemism in the Australian Wet Tropics rainforest: evidence from flightless insects. Invertebrate Systematics 16: 605-619.

COMMENTS ON THE TAXONOMIC STATUS OF *CYRTODACTYLUS ABRAE* WELLS 2002. *Memoirs of the Queensland Museum 49(2): 648. 2004:-* Wells & Wellington (1983, 1985) considered Australian populations of *Cyrtodactylus louisiadensis* to be distinct from the Louisiade Archipelago population described by De Vis, 1892. Accordingly, they resurrected from synonymy the specific name *tuberculatus* Lucas & Frost, 1900 (originally combined with *Hoplodactylus*) that had been applied to specimens collected from the Endeavour River, although they failed to provide any morphological definition or diagnosis for the species. Wells (2002) further split Australian *C. louisiadensis* populations, recognising *C. tuberculatus* as an inhabitant of 'dry sclerophyll forest' while *C. abrae* sp. nov. was said to occur in 'lowland tropical rainforest'. It is found as 'an apparently isolated population in the mountain ranges near Princess Charlotte Bay of far northern Cape York Peninsula' while *C. tuberculatus* has a distribution extending from 'about the Atherton Tablelands to the Cooktown district, on southern Cape York Peninsula'. The type locality for *C. abrae* is Iron Range, with the holotype being 'the largest specimen from the type locality in the Queensland Museum collection'.

Cyrtodactylus abrae was distinguished from *C. tuberculatus* by a number of pattern differences and the way the tail is held 'when at rest'. In *C. abrae* there are 4 bands on the body and 7 rings on the tail (vs. 6 bands, 13 rings in *C. tuberculatus*). It has pale-edged body bands that fade out before reaching the ventrolateral surface of the body (vs. dark-edged, extending down sides of body). Further differences include degree of mottling on head and limbs (uniform colouration in *C. abrae* vs. mottled) and tail posture when resting (horizontal curve in *C. abrae* vs. vertical).

In searching the Queensland Museum's collection to identify the type specimen of *C. abrae*, no specimens from Iron Range were found. The existence of a 'lowland tropical rainforest' form of *C. louisiadensis* that holds its tail in a horizontal curve is highly dubious. The Australian Museum has no *Cyrtodactylus* specimens from Iron Range, nor do there appear to be any field observations from this locality (K. McDonald and D. Storch, Queensland EPA; L. Leung, University of Queensland, Gatton, pers. comms.).

The form recognised by Wells & Wellington (1983, 1985) as *C. tuberculatus* (Lucas & Frost, 1900) may prove to be valid when a thorough revision of *C. louisiadensis* is undertaken. (Already large differences in the number of preanal and femoral pores between males from Australia and the Solomon Islands have been reported. Brown & Parker (1973) reported a range of 38-80 for the species but noted 'this wide range may reflect populations differences, since in our small sample those with the lowest number of pores were from Australia and those with the largest number from the Solomon Islands'.) Specimens have been examined from all Australian '*C. louisiadensis*' localities represented in the holdings of the Queensland and Australian Museums. None of these fully match the diagnosis of *C. abrae*, but are generally consistent with that of *C. tuberculatus* provided by Wells (2002). Included in this material are individuals from the rainforests of the McIlwraith Range and north of the Pascoe River mouth, both localities being within the stated range of *C. abrae*.

How did this error occur? The first published mention of a 'rainforest form' for *C. louisiadensis* appeared in Wilson & Knowles (1988). These authors presented diagnostic features to distinguish rainforest populations from what they termed the 'common form'. The features presented by these authors were perpetuated by Wells (2002) with slight rewording (Wilson & Knowles refered to the tail as 'prehensile'). Wilson & Knowles based their recognition of the 'rainforest form' on a single published photograph (Wilson pers. comm.). This appeared in Cogger (1975, pl. 67) captioned as 'Cape York Peninsula'. This photograph was replaced by an image of a specimen from the Atherton Tableland (Cogger, 1992: 210). The Cogger (1975) specimen had been borrowed from a private collection by the late Peter Rankin and was photographed in the Herpetology Section at the Australian Museum. Rankin had been told that his specimen was from Cape York (H. Cogger, pers. comm. to GS), but both he and Cogger had their doubts, suspecting that it may have originated from New Guinea. At the time, neither knew enough about Australian populations of the taxon to be confident of the specimen's provenance.

How Wilson & Knowles (1988) concluded that the 'Rainforest form is poorly documented; recorded from Iron Range.' cannot be determined (S. Wilson, pers. comm. to GS). However, the perpetuation of this error by Wells (2002) clearly illustrates the value of ICZN recommendation 73B; 'An author should designate as holotype a specimen actually studied by him or her, not a specimen known to the author only from descriptions or illustrations in the literature.' (ICZN, 1999). Although available evidence strongly suggests that the description of *C. abrae* is based on a published photograph, the type description makes no explicit mention that this was the case. The photograph therefore has no type status (ICZN, 1999, Article 73.1.4). The International Code of Zoological Nomenclature states that a new species name published after 1999 requires a nominated type specimen — if no type exists, then the name is invalid (ICZN, 1999, Article 16.4). The type nominated by Wells (2002), 'largest specimen from the type locality in the Queensland Museum collection', does not exist as there are no specimens from Iron Range in the Queensland Museum. Therefore *Cyrtodactylus abrae* Wells 2002 is a *nomen nudum* and has no status in zoological nomenclature.

Acknowledgements

We thank Harold Cogger and Steve Wilson for helping to clarify events and for suggesting improvements to the manuscript.

Literature Cited

BROWN, W.C. & PARKER, F. 1973. A new species of *Cyrtodactylus* (Gekkonidae) from New Guinea with a key to species from the island. Breviora 417: 1-7.

COGGER, H.G. 1975. Reptiles and Amphibians of Australia. (Reed: Sydney).

1992. Reptiles and Amphibians of Australia. (Reed Books: Chatswood).

ICZN 1999. International Code of Zoological Nomenclature. (International Trust for Zoological Nomenclature: London).

WELLS, R.W. & WELLINGTON, C.R. 1983. A synopsis of the class Reptilia in Australia. Australian Journal of Herpetology 1(3-4): 73-129.

1985. A classification of the Amphibia and Reptilia of Australia. Australian Journal of Herpetology Supplementary Series 1: 1-61.

WELLS, R.W. 2002. Taxonomic notes on the genus *Cyrtodactylus* (Reptilia: Gekkonidae). Australian Biodiversity Record 3: 1-8.

WILSON, S.K. & KNOWLES, D.G. 1988. Australia's Reptiles. A Photographic Reference to the Terrestrial Reptiles of Australia. (Collins Publishers Australia: Sydney).

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RANGE EXTENSION AND ADDITIONAL HABITAT TYPE FOR *PLANIGALE TENUIROSTRIS* (MARSUPIALIA: DASYURIDAE) IN CENTRAL QUEENSLAND

WAYNE HOUSTON, ALISTAIR MELZER, STEVE VAN DYCK AND GAIL TUCKER

Houston, W.A., Melzer, A., Van Dyck, S. & Tucker, G. 2004 06 30: Range extension and additional habitat type for *Planigale tenuirostris* (Marsupialia: Dasyuridae) in central Queensland. *Memoirs of the Queensland Museum* **49**(2): 649-652. Brisbane. ISSN 0079-8835.

The range of *Planigale tenuirostris* is extended approximately 370km north to Mt Isa (20.4°S, 139.2°E) and 340km northeast to Newlands mine (21.2°S, 147.9°E) west of Mackay into the subhumid tropics. Habitat data from three fauna surveys and nine sites show *P. tenuirostris* associated with cracking clay soils, confirming the pattern found elsewhere. In central Queensland, *P. tenuirostris* was commonly found in association with woodlands on clay soils that had a denser groundcover than that reported for *P. tenuirostris* in other biomes such as semiarid landscapes. Populations of *P. tenuirostris* were found in association with both lightly grazed land and buffer zones adjacent to mined landscapes indicating potential for ecologically sustainable land use. However, three of the four central Queensland Regional Ecosystem types in which *P. tenuirostris* was found are conservation-listed. It is, therefore, of concern that the Central Brigalow Belt had Queensland's greatest rate of clearing during 1997-1999. ❑ *Planigale ecology, range extension, habitat requirements, land clearing, conservation, habitat loss.*

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The Narrow-nosed Planigale (*Planigale tenuirostris*, Troughton, 1928) is a small (4-9g), nocturnally active, insectivorous dasyurid of inland Australia (Read, 1995). Although regarded as a species of arid and semiarid Australia (Morton, 1982), its documented range in Queensland (S of 23° S near Aramac and W of 152°E near Warwick) extended to subhumid sub-tropical climates near Monto (24.6°N, 151.2°E) (Ingram & Raven, 1991). Typically *P. tenuirostris* is found in association with cracking clay soils (Read, 1995). The deeply cracked clay is thought to provide refuge from climatic extremes in winter and summer and shelter from predation (Andrew & Settle, 1982; Denny, 1982). *Planigale tenuirostris* has been found in association with a variety of habitat types including low shrublands and tussock grasslands within arid landscapes (Morton, 1982); vegetated creek flats, grasslands and mallee scrubs (Read, 1995); and river flood plains, lake edges, gibber plains and stony hills with grass, chenopod shrub or woodland (Denny, 1982).

METHODS

Two sources of data were available — unpublished locality data from specimens held by the Queensland Museum and fauna surveys by Central Queensland University (CQU). Both data sources were used to revise the distribution of *P. tenuirostris* while only the latter was used to describe the habitat of this species. All CQU specimens were captured in drift-fence pitfall traps (25-30m fences with 5-6 20litre pitfall buckets at 5m intervals) that were checked twice daily over 10 days. Habitat was described semi-quantitatively by plant community composition and structure, and soil type.

RESULTS

The range of *P. tenuirostris* was extended approximately 370km north to Mt Isa (20.4°S, 139.2°E) and 340km northeast to Newlands mine (21.2°S, 147.9°E) west of Mackay (Table 1). This range encompassed the subhumid tropics (rainfall in the Newlands region averages over 600mm) in addition to arid, semiarid and sub-humid subtropical regions.

All sites where *P. tenuirostris* was found were typified by cracking clay soils (Table 2) and, at the two surveys where comparative data were available (Tick Hill and Newlands, Table 2), *P. tenuirostris* was not found associated with sites lacking cracking clay soils confirming the pattern found elsewhere. Clay soil type of at least two of the five study sites was heavy black clay rather than the red or gray clay indicated by Denny (1982) as typical of the habitat of *P. tenuirostris*.

TABLE 1. Queensland locality records for *P. tenuirostris* derived from unpublished (post-1989) QM records and Central Queensland University (CQU) fauna surveys. [1] Houston et al. (1996); [2] Houston et al. (1999); [3] Houston et al. (2003); [4] Confirmed by hair analysis.

Locality	Latitude (S)	Longitude (E)	Date	QM Registration Number
QM records				
3.5km W of Mt Isa	20.38	139.23	31.4.92	QM JM9322
Durrie Station	25.56	139.56	May 92	QM JM10198
Murphys Ck., Lockyer Valley (subfossilised remains)	27.28	152.05	12.11.92	QM JM10198
10km N of Dulacca	26.30	149.45	June 95	QM JM11212
Lake Broadwater	27.21	151.06	25.8.95	QM JM10988
Diamantina NP	23.46	141.09	Sept. 95	QM JM11136
CQU fauna survey records				
1. Poitrel Mining Lease [1], 30km SE of Moranbah	22.05	148.16	4.10.96	QM JM11504
2. Poitrel Mining Lease, 30km SE of Moranbah	22.05	148.16	6.10.96	Field identification [4]
3. Tick Hill Mining Lease [2], 100km south of Cloncurry	21.65	139.92	7.8.99	QM JM13340
3. Tick Hill Mining Lease, 100km south of Cloncurry	21.65	139.92	7.8.99	QM JM13341
4. Newlands Mining Lease [3], 20km north of Glenden	21.19	147.94	26.6.02	QM JM15060
5. Newlands Mining Lease, 20km north of Glenden	21.23	147.88	26.6.02	Field identification [4]

Grassy woodlands were the dominant vegetation at 3 of the 5 sites where habitat data were available (Table 2), suggesting that where this vegetation type occurs on clay soils it supports *P. tenuirostris*. A fourth woodland site was a Brigalow vegetation type with a grass and shrub understorey and shrubs prevalent along drainage lines. The only grassland site was an alluvial plain with deep cracks in the clay soil. The groundstorey of all 5 sites was dominated by grasses or had a combination of grasses and shrubs (Table 2). Two sites where habitat characteristics were quantified, had a mid-dense to dense (i.e. >30%) groundcover. These high levels of groundcover vegetation were found to persist into the late dry season.

DISCUSSION

Comparisons of subhumid tropics *P. tenuirostris* inhabit with semiarid and arid landscapes suggest a fundamental difference in habitat structure between these landscapes. The vegetation cover of semiarid and arid landscapes of central Australia was regarded either as sparse or seasonally sparse (Andrew & Settle, 1982) or typified by 'at least some vegetative cover' (Denny, 1982). Read (1987), in an investigation of habitat descriptors, found a relationship between *P. tenuirostris* abundance and groundcover height but not percentage cover. The greater availability of groundcover within the sites inhabited by *P. tenuirostris* in central Queensland suggests that in subhumid tropical landscapes a moderately dense groundcover (grass and/or shrub), in combination with cracking clay soils, may be an important component of the species' preferred habitat.

The 2 new records from central Queensland (Poitrel and Newlands) both lie in Province 6 of the Brigalow Belt bioregion and within the Central Brigalow Belt 'Regional Vegetation Management Plan' area (Accad et al., 2001). Three of the 4 Regional Ecosystem types in which *P. tenuirostris* was found in central Queensland are conservation-listed (Table 2). Because the Central Brigalow Belt had Queensland's greatest rate of clearing during 1997-1999 (Accad et al., 2001) there is concern that if these current land clearing practices were to continue at the same rate it could impact adversely on the conservation status of these *P. tenuirostris* populations.

Three of the 5 sites where *P. tenuirostris* was discovered in CQU fauna surveys were grazed (Table 2) suggesting that persistence of *P. tenuirostris* may be possible under light grazing. Whether such a level of land use is ecologically sustainable would require additional information on grazing history and population trends of *P. tenuirostris*. Despite their contribution to land clearing in the region, mined landscapes that incorporate buffer zones offer the potential to provide 'de facto' conservation reserves for vegetation types supporting fauna such as *P. tenuirostris*. These areas may be particularly important for fauna of vegetation associated with

TABLE 2. Description of *P. tenuirostris* habitat at CQU fauna survey sites (Sites sampled using equivalent methods at which *P. tenuirostris* was not found are also shown in the table). [1] Olgers & den Hertog (1968).

Vegetation Description (& RE, EPA, 2002)	Locality	Geology	Soil Type	Notes
Sites at which *P. tenuirostris* was present				
1. *Eucalyptus populnea* open woodland with sparse *Acacia harpophylla* and *Lysiphyllum hookeri* understorey; grassy groundcover. (RE11.9.10 / of concern)	Poitrel	Palaeozoic sedimentary [1]	Texture-contrast and cracking clays	Well grassed gently sloping alluvial terrace bordering riparian creek vegetation on black clay soils
2. Grassy open woodland/forest of *Eucalyptus populnea*, *Corymbia tessellaris*, *Eucalyptus tereticornis*, *Corymbia dallachiana*, *Corymbia clarksoniana* and *Eucalyptus orgadophylla*; grassy groundcover, grazed. (RE 11.3.4 / of concern)	Poitrel	Alluvial or unconsolidated [1]	Cracking clay	Alluvial terrace bordering riparian edge
3. Tussock grassland with scattered trees on a gently sloping plain. Gilgais present, grazed. (RE 1.3.4 / not of concern)	Tick Hill	Alluvial plains over Precambrian rocks	Cracking clay	Flat terrain forming a run-on area
4. *Eucalyptus orgadophylla* and *Corymbia erythrophloia* open woodland over a closed grassland on undulating black self-mulching clay soils, grazed. (RE 11.9.2 / not of concern)	Newlands	Sedimentary rocks forming cracking clay soils	Cracking clay	Undulating plains (basal area $5m^2$ ha^{-1})
5. Low forest of Brigalow (*Acacia harpophylla*) over a sparse midstorey of *Eremophila* and patchy ground cover of *Carissa ovata*, grasses and herbs on clay soils. *Eucalyptus brownii* occurs along ridgelines. Gilgais present. (RE 11.9.1 or 11.9.5 / both endangered)	Newlands	Sedimentary rocks forming clays and cracking clay soils	Cracking clay	Lower to upper slopes of low hills (basal area $12m^2$ ha^{-1})
Sites at which *P. tenuirostris* was absent				
6. Spinifex (*Triodia burkensis*) tussock grassland with scattered low trees and shrubs on the lower colluvial slope of Tick Hill. (RE 1.11.3 / not of concern)	Tick Hill	Pre-Cambrian folded rocks	Skeletal soils and shallow loams	Lower colluvial slope
7. Dense (closed in wet season) shrubland with emergent *Brachychiton* spp. and *Eucalyptus* spp. on well drained red soils. (RE 11.8.13 / endangered)	Newlands	Igneous rocks	Red earths	Hillslopes and tops (basal area $8m^2$ ha^{-1})
8. Tall open woodland of *Eucalyptus tereticornis*, *Casuarina cunninghamiana* and *Melaleuca bracteata* with a midstorey of *Ficus* sp., *Cassia brewsteri*, *Melaleuca bracteata*, and *Santalum* sp. over a mid-dense grass groundcover. (RE 11.3.25 / not of concern)	Newlands	Alluvial	Alluvial soils	Creek banks (basal area $12m^2$ ha^{-1})
9. *Eucalyptus crebra* open woodland over sparse grassland on ridges. (RE 11.11.1 / not of concern)	Newlands	Old sedimentary and metamorphosed rocks	Weathered red soils	Low rises, hills and ranges (basal area $5m^2$ ha^{-1})

lowlands as these are more extensively affected by land clearing than vegetation of hills and ranges within the Brigalow Belt bioregion (Houston & Melzer, 2004).

ACKNOWLEDGEMENTS

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LITERATURE CITED

ACCAD, A., NELDNER, V.J., WILSON, B.A. & NIEHUS, R.E. 2001. Remnant Vegetation in Queensland: analysis of pre-clearing, remnant 1997-1999 regional ecosystem information. (Queensland Herbarium, Environmental Protection Agency: Brisbane).

ANDREW, D.L. & SETTLE, G.A. 1982. Observations on the behaviour of species of *Planigale* (Dasyuridae, Marsupialia) with particular reference to the Narrow-nosed Planigale (*Planigale tenuirostris*). Pp. 311-324. In Archer, M. (ed.) Carnivorous marsupials Vol. 1. (Royal Zoological Society of New South Wales: Sydney).

DENNY, M.J.S. 1982. Review of planigale (Dasyuridae, Marsupialia) ecology. Pp. 131-138. In Archer, M. (ed.) Carnivorous marsupials Vol. 1. (Royal Zoological Society of New South Wales: Sydney).

ENVIRONMENT PROTECTION AGENCY 2002. Queensland Herbarium, Regional Ecosystem Description Database [Online], http://www.epa.gov.au/environment/science/herbarium/regional ecosystems/introduction.html, 24 July 2003. (Environmental Protection Agency: Queensland).

HOUSTON, W. & MELZER, A. 2004. Importance of range woodlands for conservation and biodiversity using the Brigalow Scaly-foot and the Common Rock-rat as examples. In, Remnant Vegetation in the Brigalow Belt – Management

and Conservation – Conference Proceedings. (Central Queensland University: Rockhampton).

HOUSTON W.A., MELZER, A. & PICKERING, G. 1996. Flora and fauna of Poitrel Mining Lease near Moranbah in Central Queensland. Unpubl. report to BHP Coal. (Centre for Land and Water Resources, Central Queensland University: Rockhampton).

HOUSTON, W., MELZER, A., PRICE, M., MCKENNA, L., LOWRY, R. & TUCKER, G. 2003. Fauna survey of Newlands Coal Mine (surface), Winter 2002 and Summer 2003. Unpubl. report to Newlands Coal. (Terrestrial Ecology Programme, Centre for Environmental Management, Central Queensland University: Rockhampton).

HOUSTON, W., MELZER, A. & TANGEY, B. 1999. Fauna and flora survey of Tick Hill, January 1999 and August 1999. Unpubl. report to SKM. (Centre for Land and Water Resource Management, Central Queensland University: Rockhampton).

INGRAM, G.J. & RAVEN, R.J. (eds) 1991. An atlas of Queensland's frogs, reptiles, birds and mammals. (Queensland Museum: Brisbane).

MORTON, S.R. 1982. Dasyurid marsupials of the Australian arid zone: an ecological review. Pp. 117-130. In Archer, M. (ed) Carnivorous marsupials Vol. 1. (Royal Zoological Society of New South Wales: Sydney).

OLGERS, F. & DEN HERTOG, J. 1968. Australian 1:250,000 Geological Series, Clermont, Queensland, Sheet SF55-11. (Bureau of Mineral Resources, Geology and Geophysics and the Geological Survey of Queensland: Brisbane).

READ, D.G. 1987. Habitat use by *Sminthopsis crassicaudata, Planigale gilesi* and *Planigale tenuirostris* (Marsupialia: Dasyuridae) in semiarid New South Wales. Australian Wildlife Research 14: 385-396.

1995. Narrow-nosed Planigale *Planigale tenuirostris*. Pp. 113-115. In Strahan, R. (ed) The mammals of Australia. (Australian Museum/Reed: Sydney).

FAUNAL SURVEY. I. THE DISTRIBUTION OF AQUATIC GASTROPODS OF THE NEW ENGLAND TABLELANDS

MAREE KOCH

Koch, M. 2004 06 30. Faunal survey. I. The distribution of aquatic gastropods of the New England Tablelands. *Memoirs of the Queensland Museum* **49**(2): 653-658. Brisbane. ISSN 0079-8835.

This survey of the distribution and abundance of aquatic gastropods of the New England Tablelands updates the information published by Simpson & Stanisic (1986) for the same region. All species showed marked reduction in both distributional ranges and abundances with no specimens of *Forsancylus enigma* found. Some seasonal loss of aquatic habitats within the Tablelands occurs annually, however the severity of the drought (January 2002 to present) has caused more extensive habitat loss and consequent loss of individual populations of aquatic snails. It is hypothesised that a combination of higher stock numbers and increased clearing of vegetation may be contributing to the reduction of aquatic snails as water levels are lowered and vertebrate faeces pollute habitats. ❐ *Aquatic gastropods, New England Tablelands, distribution, survey, pollution, habitat degradation.*

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This survey of aquatic gastropods of the New England Tablelands, New South Wales, was conducted between February 2000 and February 2003 and parallels a component of the Simpson & Stanisic (1986) survey of the same region (Fig.1). The region possesses a diversity of habitats that reflect the variations in both topography and climate experienced there. Temperate woodland partially cleared for agricultural use is abundant along the central highlands, merging with undisturbed temperate rainforests and wet sclerophyll forests along the eastern escarpment. The western slopes blend out into the alluvial plains west of Inverell and Barraba. Habitats are vulnerable and their existence is governed by climatic fluctuations within four distinct annual seasons correlated with the large altitudinal range of 1000-1500 metres across the region (Walker, 1977).

The aims of the survey were to establish the current distributional ranges of the aquatic gastropods in accordance with the initial survey of the New England Tablelands as described by Simpson & Stanisic (1986) and Heatwole & Simpson (1986); and to identify the trematode species infecting these aquatic molluscs (Koch, 2003a, 2003b). Terrestrial gastropods were not included in the current survey.

METHODS

The Australian Biogeographical Integrated Grid System (ABIGS) was used to map all species, in accordance with Brook (1977) and Simpson & Stanisic (1986). A grid of 5' longitude by 5' latitude was superimposed across the survey area, with each cell representing a 'quarter-cell' in the ABIGS system, each of these cells covering 76km^2. Shading of that cell indicates presence of a species in any part of a quarter-cell. Many quarter-cells were visited at least twice within the research period, with a final survey of the region completed between November 2002 and February 2003. Multiple visits to many sites at different seasons within the study period ensured that the possibility of seasonal occurrences of some species of gastropods was covered adequately.

Collections were made under logs and stones and amongst vegetation within dams, creeks and rivers, swamps, and backwaters using a dip net. Close examination of substrates and the stalks and leaves of aquatic vegetation was done by hand. Grid references from the original collection records (supplied by R. Simpson, 2000) were used to ensure that all sites visited during the original survey (Simpson & Stanisic, 1986) were again checked during this survey period. Collections were also made at locations other than those noted by Simpson & Stanisic (1986). Identification of all species was confirmed using the key to the terrestrial and freshwater gastropods of the New England region in Simpson & Stanisic (1986), and the non-marine mollusc key by Smith & Kershaw (1979). Any doubtful specimens were examined by Professor R. Simpson.

RESULTS

The basic features of shell formation and size of each gastropod species surveyed are illustrated in Fig. 2. Without exception, all species

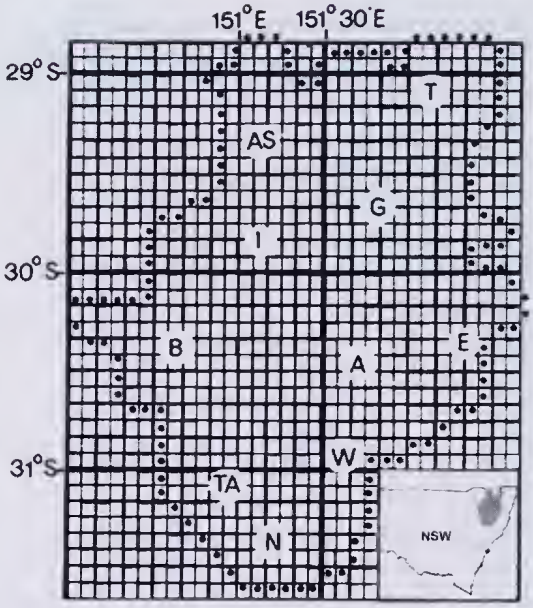

FIG. 1. ABIGS system grid superimposed over the New England region with the surveyed area enclosed by the solid dots. (AS, Ashford; A, Armidale; B, Barraba; E, Ebor; G, Glen Innes; I, Inverell; N, Nundle; TA, Tamworth; T, Tenterfield; W, Walcha) (After Simpson & Stanisic, 1986).

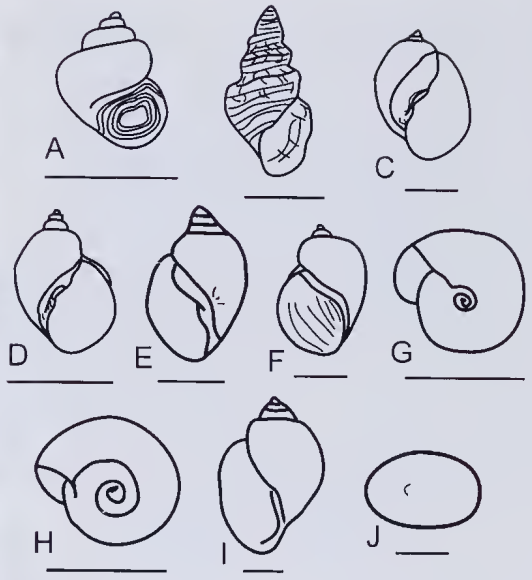

FIG. 2. Aquatic snail species of the survey area. A, *Gabbia vertiginosa*; B, *Plotiopsis balonnensis*; C, *Austropeplea lessoni*; D, *Austropeplea tomentose*; E, *Glyptophysa* sp.; F, *Isidorella* sp.; G, *Gyraulus metaurus*; H, *Pygmanisus pelorius*; I, *Physa* sp.; J, *Forsancylus enigma*. Scale bars: A-D = 5mm; E-F = 4mm; G-J = 2mm. (Source: M. Koch).

demonstrated reduced distribution, with no specimens of *Forsancylus enigma* being collected (Figs 3-12). At Dangars Lagoon 10km SE of Uralla, large numbers of dead *Physa* were collected on 2 occasions during 2000. No live snails were found at this location throughout the survey period.

Every species also demonstrated reduced abundance compared with the descriptions of populations by Simpson & Stanisic (1986). An exception to this was one population of *Gabbia vertiginosa* at Saumarez Road swamp (5km SSW of Armidale) where many hundreds were observed at every collection up to March 2002.

The Bureau of Meteorology Australia (BMA), on 8th October 2002, formally declared the entire New England Tablelands to be in the tenth month of the most profound drought to be experienced in recorded history. At the time of publication, the drought was still continuing across the region, with some rainfall between February and April 2003 providing surface water. As a direct consequence of loss of surface water and increased drawing on subterranean-fed bores and springs, swamp backwaters, roadside culverts and most drains and shallow water courses began to dry out from June 2002 onwards. Creeks and rivers that still contained water by February 2003 were reduced in both size and volume of flow. Figure 13 portrays the reduction of rainfall across the entire region in past years as compared to the mean annual rainfall calculated for the area between the years 1857 to 1997 by the Bureau of Meteorology Australia. For the 36 months January 2000 to December 2002, the survey region registered a departure from and below the Long Term Average (LTA) annual rainfall value of 500mm for the western and central sections and 1000mm for the eastern escarpments (BMA, 2003). The LTA is calculated based on the current international standard thirty year average annual rainfall for the area from 1961 to 1990 (BMA, 2003). The average annual evaporation rate for the Tablelands between January 2000 and December 2002, at 1232mm, was 15mm higher than the LTA (BMA, 2003). Weather patterns indicate a continuance of dry conditions to the spring of 2003.

DISCUSSION

Seasonal loss of aquatic habitats is a normal occurrence on the Tablelands as the heavy frosts

and lower rainfall of winter coincide causing either reduction or complete removal of many shallow and vulnerable environments. Collections at sites during all seasons throughout the survey period ensured that such environmental factors had minimal impact on distributional patterns. The combined effects of lower rainfall and higher evaporation rates across the region leading into the current drought have caused further loss of habitats. Such harsh conditions can explain reduced species distribution from February 2000 to the present time. What factors could be responsible for such marked reductions in ranges between the first survey in 1986 and 2000? The aspect of human error must be considered to some extent as even the most experienced and diligent collector can miss a specimen. I believe this to have had a minor impact on the survey results.

The majority of wetlands are either surrounded by, or situated on, pastoral and agricultural leases, as are most of the creeks, dams and swamps within the survey region. The use of superphosphates on improved pastures and insecticides on crops in paddocks bordering aquatic habitats impact on the aquatic fauna by bringing about changes in water quality as these chemicals leach into the water systems (Ridge, 1995 in Ponder, 1997; Michaelis, 1984). High levels of land clearing and disturbance of country immediately surrounding aquatic habitats can also lead to siltation of microhabitats through topsoil erosion (Ponder, 1997).

Increased stock levels within the New England in response to the good seasons of the 1990's have impacted on the banks and substrates of dams and water courses which are largely unfenced (McKeon et al, 2000; pers. obs.). Higher stock numbers cause an increased draw on water supplies and significant organic matter being introduced via vertebrate

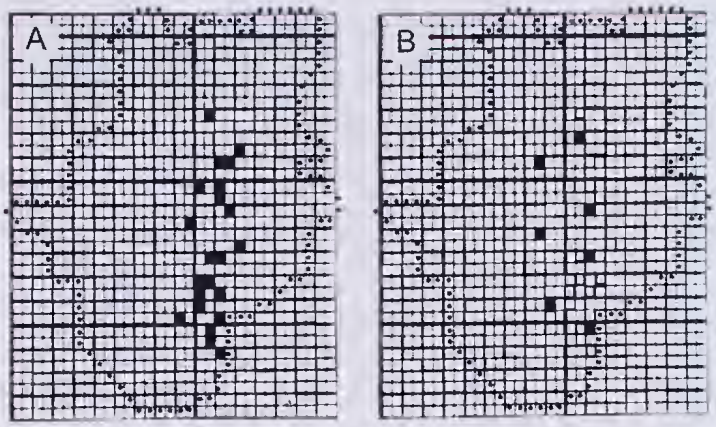

FIG. 3. Distribution of *Gabbia vertiginosa*. A, 1986 survey; B, current distribution.

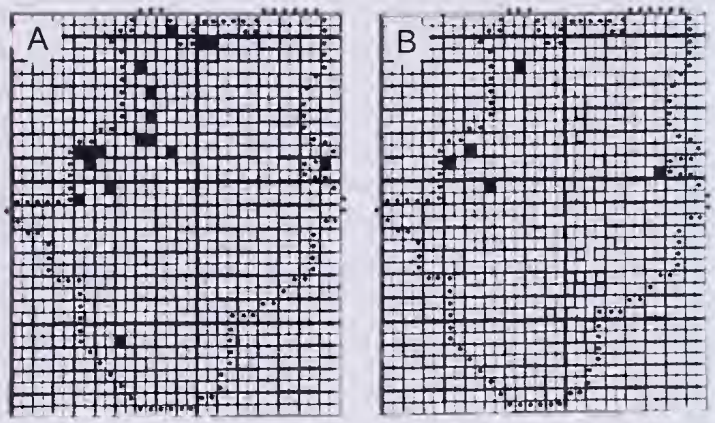

FIG. 4. Distribution of *Plotiopsis balonnensis*. A, 1986 survey; B, current distribution.

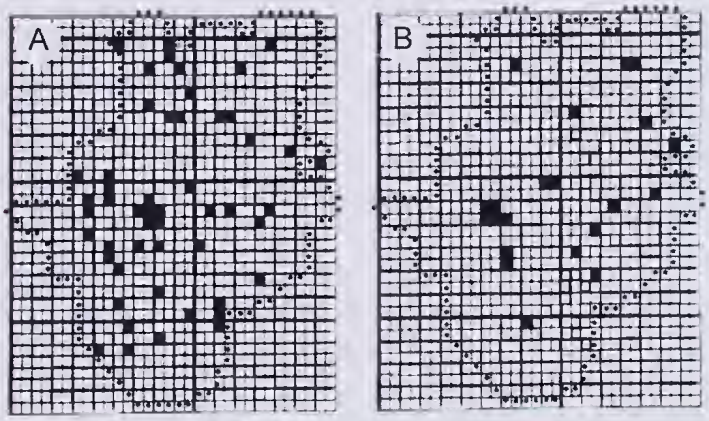

FIG. 5. Distribution of *Austropeplea lessoni*. A, 1986 survey; B, current distribution.

faeces, which in turn affects water quality by raising ammonium levels (Campbell & Doeg, 1989; Ponder, 1997). Once ammonium concentrations increase to 5mg/l or higher in standing or slow-flowing water, habitat conditions become toxic to invertebrate life (Romanowski, 1994). The tendency of regional pastoralists to retain high stock numbers during drought or dry seasons leads to further degradation of habitats that are already struggling for survival (McKeon et al, 2000).

Establishing the data on which to base sound responses to the above hypotheses is beyond the scope of the present study and requires a statistically designed survey over time to determine if there is a real decrease in species populations and distributional ranges. Comparing the results of the two surveys leaves no validity for conclusions on population increase or decrease to be correctly drawn. It is a situation deserving considerable concern, however. Due to their limited abilities to disperse, many of our aquatic snails have very narrow distribution ranges and some of the taxa present in New South Wales are endemic to this state (Ponder, 1997). If species distributional ranges and abundances have reduced to the extent indicated by the current survey in two decades, what effects will the current drought and agricultural practices have upon already vulnerable populations? Do we risk losing some aquatic gastropods from the New England Tablelands permanently? Have some, such as *F. enigma*, already been lost?

ACKNOWLEDGEMENTS

I am grateful to Mary Notestine, and Klaus Rohde for review of the manuscript and to Rod Simpson for review, his original survey records and consultations on species identifications.

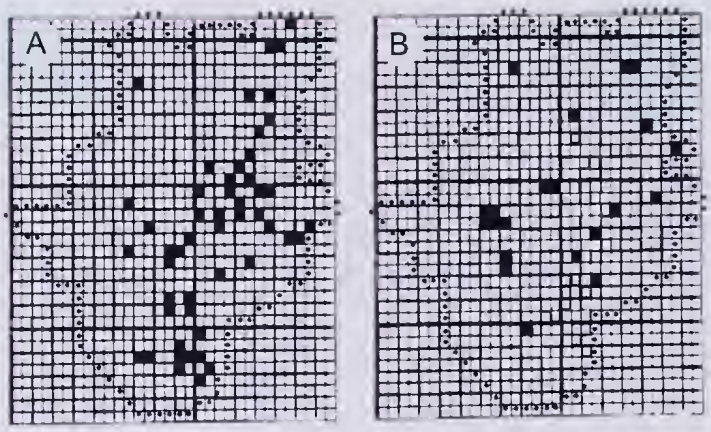

FIG. 6. Distribution of *Austropeplea tomentosa*. A, 1986 survey; B, current distribution.

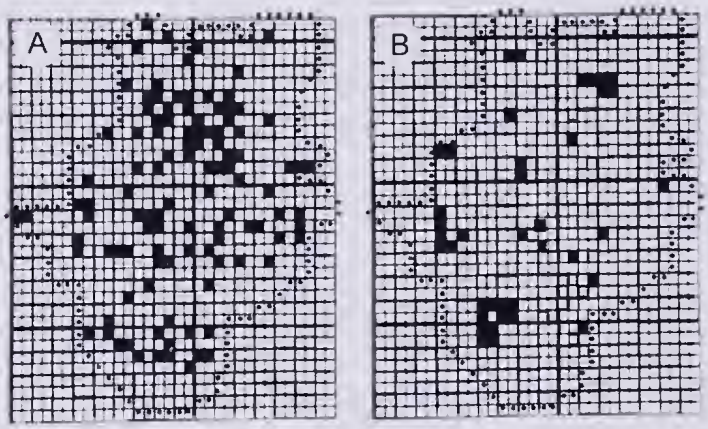

FIG. 7. Distribution of *Glyptophysa*. A, 1986 survey; B, current distribution.

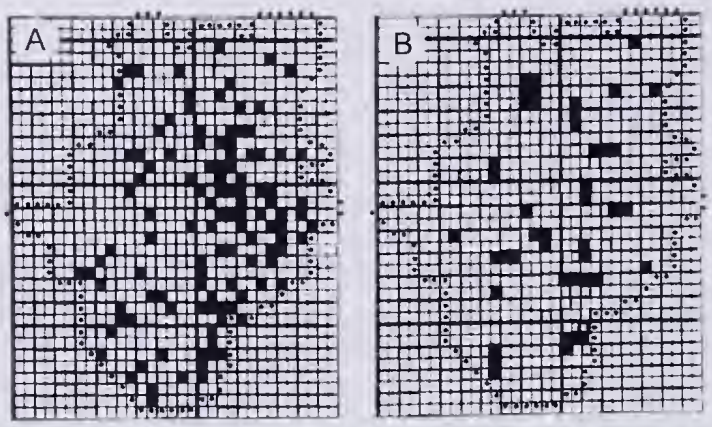

FIG. 8. Distribution of *Isidorella*. A, 1986 survey, B, current distribution.

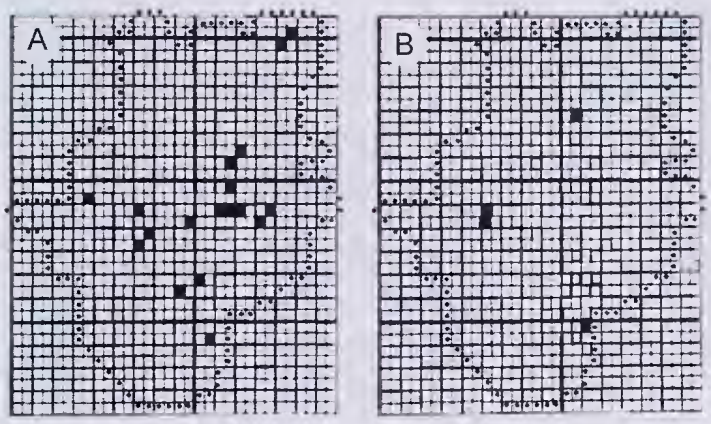

FIG. 9. Distribution of *Gyraulus metaurus*. A, 1986 survey; B, current distribution.

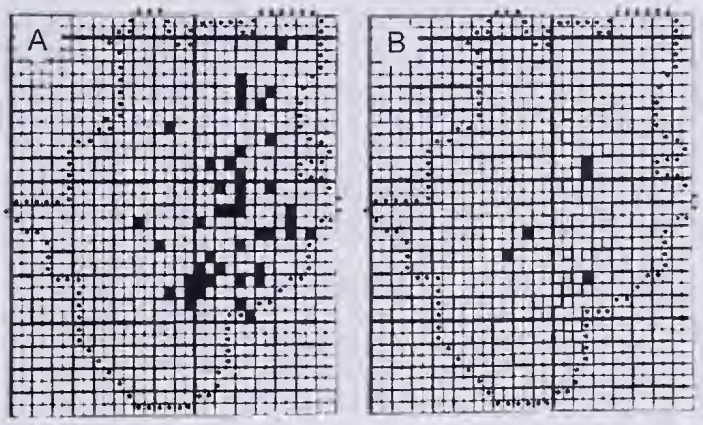

FIG. 10. Distribution of *Pygmanisus pelorius*. A, 1986 survey; B, current distribution.

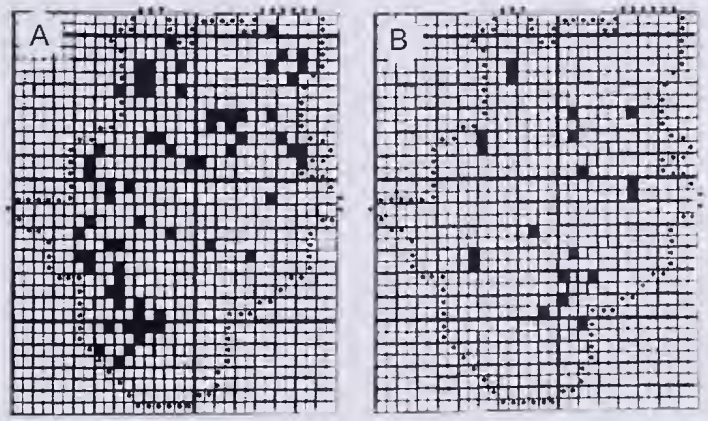

FIG. 11. Distribution of *Physa* sp. A, 1986 survey; B, current distribution.

LITERATURE CITED

BUREAU OF METEOROLOGY AUSTRALIA 2003. (http://www.bom.gov.au/), (Accessed 01/2002 – 06/2003).

BROOK, A.J. 1977. ABIGS (Australian Biogeographical Intergrated Grid System). Technical Manual. (Dept of Zoology: University of Melbourne).

CAMPBELL, I.C. & DOEG, T.J. 1989. Impact of timber harvesting and production on streams: a review. Australian Journal of Marine and Freshwater Research 40: 519-539.

HEATWOLE, H. & SIMPSON, R. 1986 Faunal survey of New England. I. Introduction and general description of the area. Memoirs of the Queensland Museum 22(2): 107-113.

KOCH, M. 2003. Aquatic snails and their trematodes in the New England Tablelands (New South Wales, Australia): low diversity and unstable population structure explained by unpredictable environmental fluctuations). Unpubl. PhD thesis, University of New England, Armidale, NSW.

2004. Faunal survey. II. The distribution of Digenean trematodes within the aquatic gastropods of the New England Tablelands. Memoirs of the Queensland Museum 49(2): this volume.

McKEON, G.M., HALL, W.B., YEE YET, J., STONE, G.S., CRIMP, S.J., PEACOCK, A., RICHARDS, R., TYNAN, R.W., WATSON, I.W. & POWER, S.B. 2000. Learning from history: land and pasture degradation episodes in Australia's rangelands. Environment--International (CSIRO: Canberra).

McMICHAEL, D. 1967. Australian Freshwater Mollusca and their probably evolutionary relationship: a summary of present knowledge. In Weatherely, A.H. (ed.) Australian inland waters and their fauna. (Australian National University Press: Canberra).

MICHAELIS, F.B. 1984. Possible effects of forestry on inland waters of Tasmania: a review. Environmental Conservation 11: 331-344.

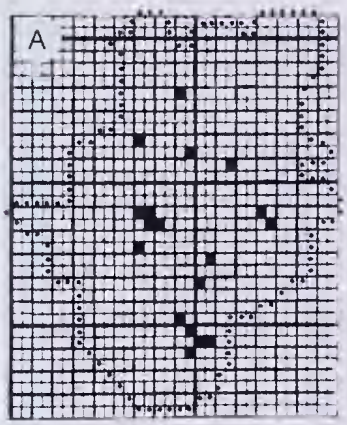

FIG. 12. Distribution of *Forsancylus enigma* sp. A, 1986 survey. This species was not found in the current survey.

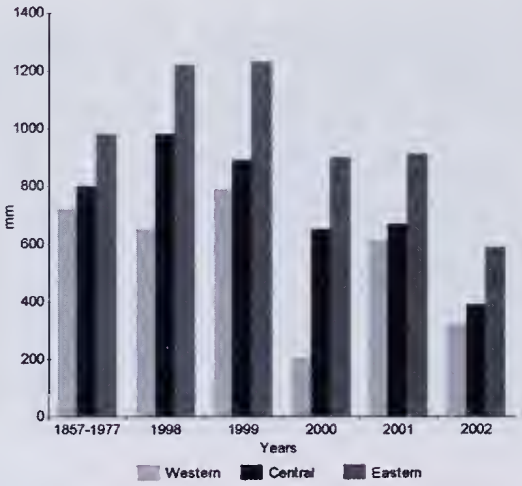

FIG.13. Annual rainfall in millimetres for the three geographical divisions within the survey region (years1998 to 2002), measured against the mean annual rainfall for the region recorded between 1857 and 1997 (134.5 years and 96% complete). Compiled by M. Koch from data recorded by the Bureau of Meteorology Australia.

PONDER, W.F. 1997. Conservation status, threats and habitat requirements of Australian terrestrial and freshwater Mollusca. Memoirs of the Museum of Victoria 56(2): 421-430.

ROMANOWSKI, N. 1994. Farming in ponds and dams – an introduction to freshwater aquaculture in Australia. (Lothian Pty Ltd: Melbourne).

SIMPSON, R. & STANISIC, J. 1986. Faunal survey of New England. ii. The distribution of gastropod molluscs. Memoirs of the Queensland Museum 22(2): 115-139.

SMITH, B. & KERSHAW, R. 1979. Field guide to the non-marine molluscs of south-eastern Australia. (Australian National University: Canberra).

WALKER, G.T. 1977. Relief. Pp. 11-16. In Lea, D.A.M., Pigram, J.J.J., Greenwood, L. (eds) An Atlas of New England, Vol. 2. (University of New England: Armidale).

FAUNAL SURVEY. II. THE DISTRIBUTION OF DIGENEAN TREMATODES WITHIN THE NEW ENGLAND TABLELANDS

MAREE KOCH

Koch, M. 2004 06 30. Faunal survey. II. The distribution of digenean trematodes within the New England Tablelands. *Memoirs of the Queensland Museum* **49**(2): 659-664. Brisbane. ISSN 0079-8835.

Trematode larval stages collected from aquatic snails across the New England Tablelands were examined and identified through morphometric analysis and where possible, transmission experiments and 28S (LSU) rDNA analysis. One monostome and three distome digenean trematode species were found in populations of *Gabbia vertiginosa* (Bithyniidae). One distome digenean was found in the snail *Glyptophysa* sp. (Planorbidae). The prevalence of all trematode species was low and their distributions limited to the central portion of the New England Tablelands. Temporal and spatial heterogeneity within both intermediate and definitive host populations may be acting as isolating mechanisms at times of recruitment of larval trematodes, limiting parasite distributional ranges through disruption of their natural transmission cycles. ❑ *Trematode, Notocotylidae, Echinostomatidae, Heterophyidae, distribution.*

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Aquatic snails collected during a survey of the New England Tablelands, New South Wales, between February 2000 and 2003 (Koch, 2004) were examined for larval stages of trematodes. Typically, such parasites utilise molluscs as intermediate hosts in two or three-host life cycles (Ginetsinskaya, 1988). Sporocyst, redia, cercaria and metacercaria stages of trematode development can be found in both terrestrial and aquatic snails, with adult parasites maturing within a definitive vertebrate host (Rohde, 2001; Haas & Haberl, 1997). Traditionally trematodes have been identified to genus and species level by obtaining a mature adult worm either by dissection out of a natural vertebrate host or by completing life cycle experiments utilising the larval forms obtained from snails collected from a natural habitat (Gibson, 1998; Wright, 1971). Whenever possible, such transmission experiments were attempted throughout this survey period. In addition to the traditional identification methods, partial sequencing of the 28S long subunit (LSU) rDNA taken from larval trematodes found during dissections of snails was undertaken at the Natural History Museum, London), (Olson et al, 2003; Littlewood & Olson, 2001).

The aims of the survey were to identify trematode species across the New England Tablelands; to establish their distributional ranges; and to identify the aquatic snails being parasitised, and thereby determine intermediate host specificity.

METHODS

The Australian Biogeographical Integrated Grid System (ABIGS) was used to map all species, in accordance with Brook (1977) and Simpson & Stanisic (1986). Aquatic snails were collected as described by Koch (2004). Snails were dissected within 24 hours of collection by crushing of the shell and the tissue examined in a cavity block under a dissecting microscope for live trematodes. Trematode specimens were fixed in either 10% hot formalin or hot saline (8.5g NaCl per 1 litre distilled water), stained with either Grenacher's carmine alum or acetocarmine, dehydrated in an alcohol series, and mounted in Canada balsam. Slides were then dried in an oven at 66°C for 14 days (Conn, 1946). Specimens required for DNA sequencing were dropped immediately upon dissection into absolute alcohol (Jousson et al., 1998). Identification of trematodes was done primarily by obtaining adult worms through life cycle experiments whenever possible, and secondarily through partial sequencing of rDNA 28S LSU by Olson and Littlewood. In all other cases, cercarial and redial life stages were used to identify species to family and/or genus using published research papers and keys (Yamaguti, 1971, 1975; McDonald, 1981). Intensity was defined as the number of cercariae observed within the snail tissues at the time of dissection (high: >100 cercariae per snail; medium: 50-100 cercariae per snail; low: <50 cercariae per snail). Prevalence was defined as

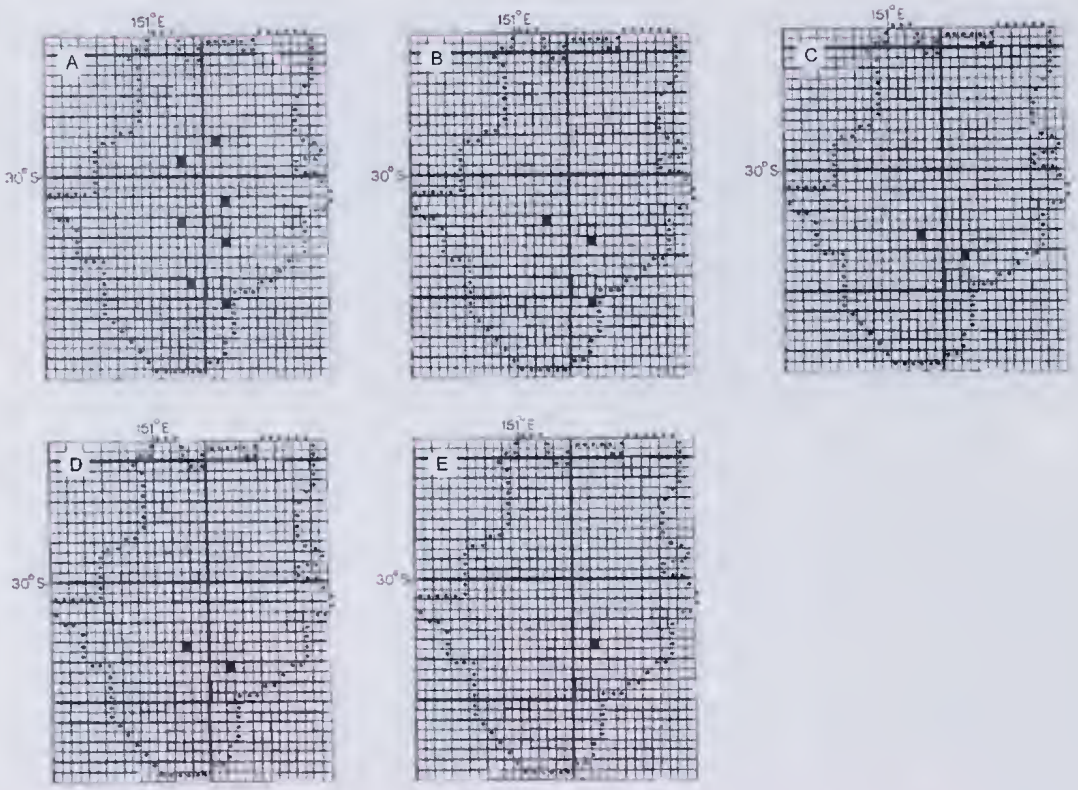

FIG. 1. Comparison of current distributional ranges of trematodes with that of their intermediate snail host, *Gabbia vertiginosa*. A, *G. vertiginosa* ; B, *Catatropis indicus*; C, *Philopthalmus* sp. nov.; D, *Echinoparyphium australis* n. sp.; E, *Ascocotyle* sp. nov. (ABIGS system grid superimposed over the New England region with the surveyed area enclosed by the solid dots — see Koch, 2004)

the percentage of snails collected that were infected by trematode larval stages.

Photographs were taken using an Olympus BH2 camera attached to a stereomicroscope, or using a digital camera attached to a Nomarski contrast microscope. Digital photographs were downloaded into Adobe Photoshop program for editing. Body parts were measured with a calibrated eyepiece graticule. Measurements are given in millimetres.

RESULTS

Two snail species were found to be parasitised. The prosobranch *Gabbia vertiginosa* (Bithyniidae) was host to 1 monostome and 3 distome digeneans: *Catatropis indicus* (Notocotylidae), *Echinoparyphium australis* sp. nov. (Echinostomatidae), *Philopthalmus* sp. nov. (Echinostomatidae), and *Ascocotyle* sp. nov. (Heterophyidae) (Figs 1-3). Adult worms of *C. indicus* and *Echinoparyphium australis* sp. nov. were obtained from life cycle experiments (Koch, 2003). Phylogenetic analysis of the LSU 28S rDNA of adult worms against 150 digenean taxa confirmed the identity of *Echinoparyphium australis* sp. nov. (Genebank accession number AY395577) and *C. indicus* (Genebank accession numbers AY222114, AY222220). PCR products could not be generated for any other trematode species. Attempts to obtain adults of *Philopthalmus* sp. nov. and *Ascocotyle* sp. nov. failed.

The rediae and cercariae of *C. indicus* always occurred alone within the gonad tissue of *G. vertiginosa*. However, the other three trematode species were found as concurrent interspecific double and triple infections within *G. vertiginosa*, all utilising gonad and digestive gland tissues. *Philopthalmus* sp. nov. established infection first within the snail. Recruitment of *Echinoparyphium australis* sp. nov. and *Ascocotyle* sp. nov. followed in that order.

Glyptophysa sp. (Planorbidae) was host to one distome digenean, *Echinostoma* sp. nov.

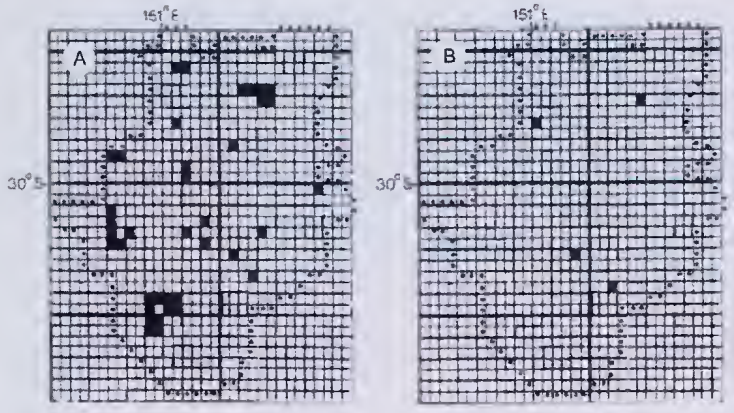

FIG. 2. Comparison of current distributional ranges of *Echinostoma* sp. nov. with that of its intermediate snail host, *Glyptophysa* sp.

(Echinostomatidae) with rediae and cercariae occurring in digestive gland and gonad tissue of the snail (Figs 2 & 3E). It was present in the snail population during all seasons, across all years. Adult worms of this species could not be obtained through transmission experiments.

C. indicus was present in the snail populations at all seasons across all collection years. The three distome species specific to *G. vertiginosa*, however, were present only between January and April of all collection years. Intermediate host specificity was high for all trematode species as demonstrated by the use of a single host species and failure of parasites to establish infections in other aquatic snail species during transmission experiments performed and described by Koch (2003). Prevalence and abundance of all trematode species are summarised in Table 1.

Detailed descriptions of parasite anatomy and life cycles, and transmission experiments can be found in Koch (2002, 2003).

DISCUSSION

Many studies have presented data to support the hypothesis that temporal heterogeneity within both definitive and intermediate host populations can bring about the isolation and even removal of a parasite species from the environment when the chronological patterns of activity of the hosts are in opposition either with the parasite or each other (Al-Kandari et al, 2000; Kuris & Lafferty, 1994; Crews & Esch, 1986; Cort et al, 1960). The trematode life cycle has evolved around this variation in both intermediate and definitive host habitat usage, and the interplay of temporal behaviour patterns of both host and parasite (Poulin, 1999a; 1999b; Poulin & Morand, 1999). Seasonal migration and other movements across and between habitats by final hosts such birds can remove or add hosts from or to the specific preferences of parasite species. By adding to the habitat, the opportunity for completion of a life cycle in one or more final hosts by one or more parasite species is greatly enhanced. Conversely, the departure of a final host from a particular habitat may cause the loss (seasonally or permanently) of one or more parasite species due to the interruption of the natural cycle of transmission between intermediate and definitive hosts (Combes et al, 1994; Kuris & Lafferty, 1994). Such temporal pulses in host populations will bring about pulses in parasite populations actively associated with those hosts (Smith, 2001). An inference can be drawn from my study of a degree of temporal variation in both parasite and intermediate host populations between seasons as indicated by the presence of distome species in *G. vertiginosa* only in mid and late summer months. Published records show natural final hosts of the Echinostomatidae and Heterophyidae to be commonly waterbirds such as ducks, herons, and egrets (Kanev et al, 1998; Yamaguti, 1975). These species are mostly nomadic birds that are found abundantly across the Tablelands during the summer months, moving towards the warmer coastal or inland areas for winter. Such migration patterns can link habitats and thus parasite communities of intermediate hosts creating pulses in prevalence in both parasite and intermediate host populations across time (Smith, 2001). There was a consistency in my study, however, of the presence of all parasite species across years, indicating only seasonal isolation of species with in habitats as opposed to complete removal of species.

Spatial heterogeneity in parasite recruitment due to geographical isolation of snail host populations and possible definitive host habitat preferences may be responsible for the patterns and seasonality of parasite distribution along the central section of the Tablelands. This area has a high concentration of natural watercourses that attract water bird species and provide suitable habitats for first and second intermediate hosts

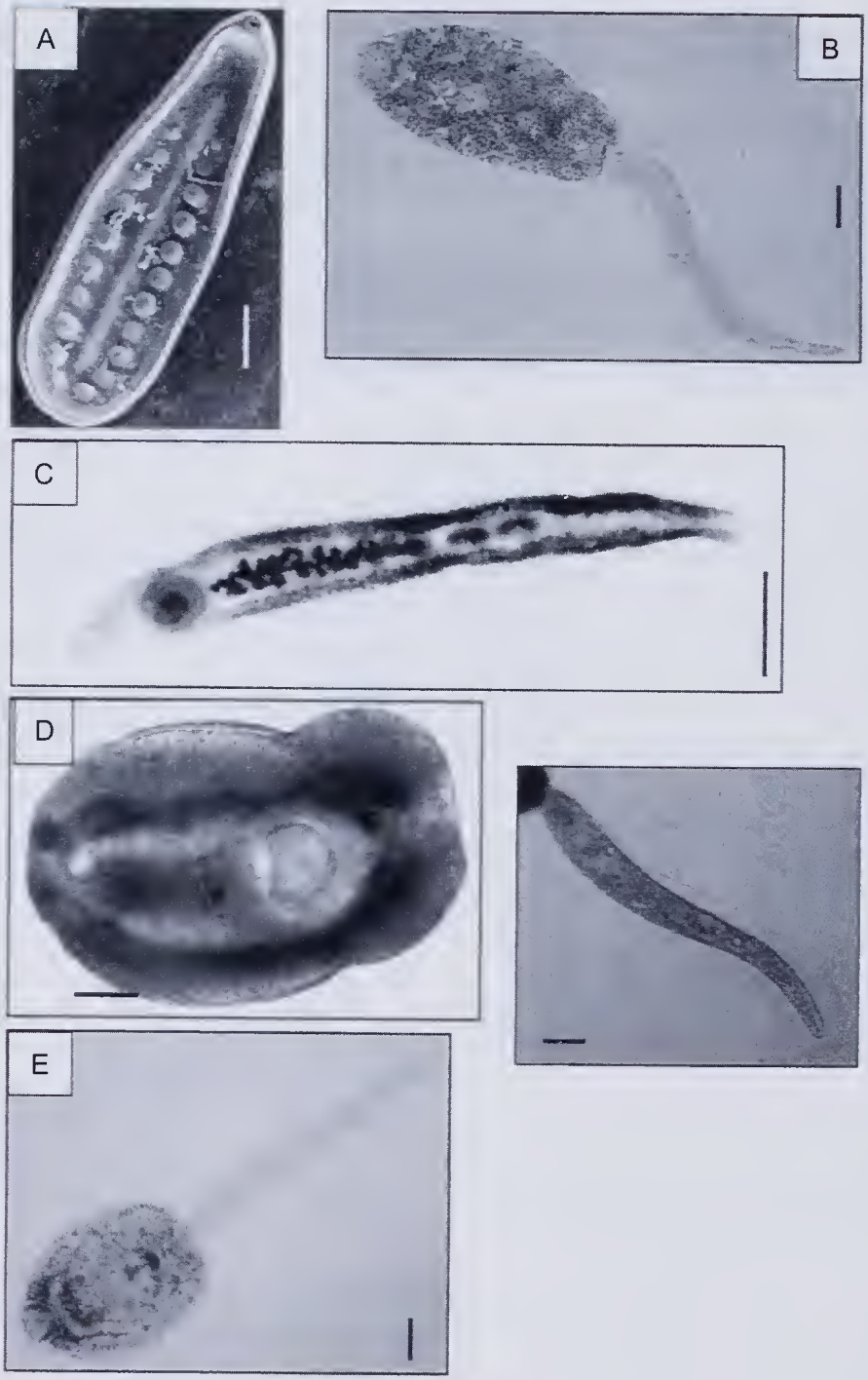

FIG. 3. Trematode species found during the survey of aquatic gastropods of the New England region. A, *Catatropis indicus* adult (SEM); B, *Philopthalmus* sp. nov. Cercaria; C, *Echinoparyphium australis* sp. nov. adult; D, *Ascocotyle* sp. nov. cercaria with close-up of tail finfold; E, *Echinostoma* sp. nov. cercaria. Scale bars: A & C = 1mm; B,D,E = 20μm.

TABLE 1. Prevalences of infection of larval trematodes within aquatic snail populations of the New England Tablelands.

Parasite	Prevalence	Intensity	Snail Host
Catatropis indicus	3.5 % (5240)	high	*Gabbia vertiginosa*
Philopthalmus sp. nov.	0.90 % (5240)	high	*Gabbia vertiginosa*
Echinoparyphium australis sp. nov.	0.30 % (5240)	medium	*Gabbia vertiginosa*
Ascocotyle sp. nov.	0.08 % (5240)	low	*Gabbia vertiginosa*
Echinostoma sp. nov.	85% (47)	high	*Glyptophysa* sp.

such as snails, fish and frogs (Douglas & Douglas, 1977). There are also many man-made dams and swamps, some of which do not support the diversity of invertebrate and vertebrate species required for completion of digenean trematode life cycles (Jacobs, 1952; pers. obs.). A large proportion of these habitats dry up for three to five months every year, concentrating snails and final hosts within a small distribution range. These factors may act as potential isolating mechanisms occurring at times of recruitment of parasites and peak snail host reproductive periods, in the summer months of October through to April. All trematode species in the study demonstrated high intermediate host specificity (Koch, 2002, 2003), a trend shown to be common particularly within the Echinostomatidae (Sapp & Loker, 2000; Korner et al, 1995). When host species demonstrate such uniquely specific assemblages of trematode species, isolation of these species over both space and time, and thus their recruitment into snail host populations, is more likely to occur than in those parasite species with low host specificity (Kuris & Lafferty, 1994).

The impact of larval stages such as rediae and cercariae on intermediate host fertility and reproduction could cause substantial host population reductions if prevalences were as high as those described in other studies (Huxham et al., 1993; Kuris, 1973; Sousa, 1993; Irwin, 1983; Pan, 1965). However, the high abundances of larval stages combined with low prevalences in the New England region provide for an environmental system within which sustainability of both host and parasite populations is possible.

ACKNOWLEDGEMENTS

I thank D.T. Littlewood and P. Olson for molecular analyses, and Mary Notestine, Klaus Rohde and Rod Simpson for reviews of the manuscript.

LITERATURE CITED

AL-KANDARI, W.Y., ABDUL-SALAM, J. & MEAKINS, R. 2000. Temporal variations in the infection of a population of *Cerithidea cingulata* by larval trematodes in Kuwait Bay. Journal of Helminthology 74: 17-22.

COMBES, C., FOURNIER, A., MONE, H.& THERON, A. 1994. Behaviours in trematode cercariae that enhance parasite transmission – patterns and processes. Parasitology 109 (Suppl S): 3-S 13.

CONN, H. 1946. Biological Stains: a handbook on the nature and uses of the dyes employed in the biological laboratory. 5th ed. (Biotech: New York).

CORT, W.W., HUSSEY, K.L. & AMEEL, D.J. 1960. Seasonal fluctuations in larval trematode infections in *Stagnicola emarginata angulata* from Phragmites Flats on Douglas Lake. Proceedings of the Helminthological Society of Washington 27: 11-13.

CREWS, A. & ESCH, G.W. 1986. Seasonal dynamics of *Halipegus occidualis* (Trematoda: Hemiuridae) in *Helisoma anceps* and its impact on fecundity of the snail host. Journal of Parasitology 77: 528-539.

CRIBB, T.H., ANDERSON, G.R., ADLARD, R.D. & BRAY, R.A. 1998. A DNA-based demonstration of a three-host life-cycle for the Bivesiculidae (Platyhelminthes: Digenea). International Journal for Parasitology 28: 1791-1795.

DOUGLAS, I. & DOUGLAS, M. 1977. Water resources. Pp. 101-126. In Lea, D.A.M., Pigram, J.J.J. & Greenwood, L. (eds) An atlas of New England. Vol 2. (University of New England: Armidale).

GIBSON, D.I. 1998. Nature and classification of parasitic Helminths. Pp. 453-477. In Collier, L., Balows, A. & Sussman, M. (eds) Topley & Wilson's microbiology and microbial infections. 9th ed. Vol 5. (Arnold Press: London).

GINETSINSKAYA, T. 1988. Trematodes, their life cycles, biology and evolution. (Amerind Publishing Co.: New Delhi).

HAAS, W. & HABERL, B. 1997. Host recognition by trematode miracidiae and cercariae. Pp. 197-227. In Fired, B. & Graczyk, T.K. (eds) Advances in trematode biology. (CRC Press: Boca Raton).

HUXHAM, M., RAFFAELLI, D.& PIKE, A. 1993. The influence of *Cryptocotyle lingua* (Digenea: Platyhelminthes) infections on the survival and fecundity of *Littorina littorea* (Gastropoda: Prosobranchia): an ecological approach. Journal of Experimental Marine Biology and Ecology 168: 223-238.

IRWIN, S.W.B. 1983. Incidence of trematode parasites in two populations of *Littorina saxatilis* (Olivi) from the North Shore of Belfast Lough. Irish National Journal 21: 26-29.

JACOBS, S. 1952. Vegetation. Pp. 14-19. In Haigh, C. (ed.) Wetlands of New South Wales. (National Parks and Wildlife Services, Sydney).

JOUSSON, O., BARTOLI, P., ZANINETTI & L. PAWLOWSKI, J. 1998. Use of the ITS rDNA for elucidation of some life-cycles of Mesometridae (Trematoda, Digenea). International Journal for Parasitology 28(9): 1403-1411.

KANEV, I., SORENSEN, R., STERNER, M., COLE, R. & FRIED, B. 1998. The identification and characteristics of *Echinoparyphium rubrum* (Cort, 1914) comb. new (Trematoda, Echinostomatidae) based on experimental evidence of the life cycle. Acta Parasitologica 43(4): 181-188.

KOCH, M. 2002. First record and description of *Catatropis indicus* Srivastava 1935 (Digenea: Notocotylidae), in Australia. Memoirs of the Queensland Museum 48(1): 147-153.

2003. Aquatic snails and their trematodes in the New England Tablelands (New South Wales, Australia): low diversity and unstable population structure explained by unpredictable environmental fluctuations. Unpubl. PhD thesis, University of New England, Armidale, NSW.

2004. Faunal survey. I. The distribution of aquatic gastropods of the New England Tablelands. Memoirs of the Queensland Museum 49(2): this volume.

KORNER, W.H.M., HUTTERER, E. WEGNER, M. & HABERL, B. 1995. Finding and recognition of the snail intermediate hosts by three species of Echinostome cercariae. 1995. Parasitology 110: 133-142.

KURIS, A.M. 1973. Biological control: Implications of the analogy between the trophic interactions of insect pest-parasitoid and snail-trematode systems. Experimental Parasitology 33: 365-379.

KURIS, A.M. & LAFFERTY, K.D. 1994. Community structure: larval trematodes in snail hosts. Annual Review of ecological Systems 25: 189-217.

LITTLEWOOD, D.T.J., CRIBB, T.H., OLSON, P.D. & BRAY, R.A. 2001. Platyhelminth phylogenetics – a key to understanding parasitism? Belgian Journal of Zoology 131: 35-46. Suppl.1.

LITTLEWOOD, D.T.J. & OLSON, P. 2001. Small subunit rDNA and the Platyhelminthes: Signal, noise, conflict and compromise. Pp. 262-278. In Littlewood, D.T.J. & Bray, R. (eds) Interrelationships of the Platyhelminthes. (Natural History Museum: London).

LO, C.T. 1995. *Echinstoma macroorchis*: life history, population dynamics of intramolluscan stages, and the first and second intermediate hosts. Journal of Parasitology 81(4): 569-567.

MCDONALD, M. 1981. Key to trematodes reported in waterfowl. (United States Department of the Interior: Fish & Wildlife service, Washington).

OLSON, P.D., CRIBB, T.H., TKACH, V.V., BRAY, R.A. & LITTLEWOOD, D.T.J. 2003. Phylogeny and classification of the Digenea (Platyhelminthes: Trematoda). International Journal for Parasitology 33: 733-755.

POULIN, R. 1999a. The functional importance of parasites in animal communities: many roles at many levels? International Journal for Parasitology 29: 903-914.

1999b. The intra- and interspecific relationships between abundance and distribution in helminth parasites of birds. Journal of Animal Ecology 68: 719-725.

POULIN, R. & MORAND, S. 1999. Geographical distances and the similarity among parasite communities of conspecific host populations. Parasitology 119: 369-374.

ROHDE, K. 2001. Parasitism. Pp. 463-484. In Encyclopedia of Biodiversity. Vol. 4. (Academic Press: New York).

SAPP, K.K. & LOKER, E.S. 2000. Mechanisms underlying digenean-snail specificity: role of miracidial attachment and host plasma factors. Journal of Parasitology 86(5): 1012-1019.

SMITH, N. 2001. Spatial heterogeneity in recruitment of larval trematodes to snail intermediate hosts. Oecologia 127: 115-122.

WRIGHT, C.A. 1971. Flukes and snails. (George Allen and Unwin Ltd.: London).

YAMAGUTI, S. 1971. Synopsis of digenetic trematodes of vertebrates. (Keigaku Publishing Co.: Tokyo).

1975. A synoptic review of life histories of digenetic trematodes of vertebrates. Vols. I & II. (Keigaku Publishing Co.: Tokyo).

A NEW SPECIES OF THE CRANGONID GENUS *PHILOCHERAS* STEBBING (CRUSTACEA: DECAPODA: CARIDEA) FROM NORTHEASTERN AUSTRALIA

T. KOMAI

Komai, T. 2004 06 30: A new species of the crangonid genus *Philocheras* Stebbing (Crustacea: Decapoda: Caridea) from northeastern Australia. *Memoirs of the Queensland Museum* **49**(2): 665-673. Brisbane. ISSN 0079-8835.

A new species of crangonid shrimp, *Philocheras brucei*, *is* described from Cairns, Queensland. The distinct lateral tooth on the antennal scale links the new species to *P. angustirostris* (De Man, 1918), *P. incisus* (Kemp, 1916), *P. kempi* (De Man, 1918), *P. parasculptus* Burukovsky, 1991, *P. sculptus* (Bell, 1847) and *P. vanderbilti* (Boone, 1935). The carination and dentition of the carapace and sculpture of the abdomen distinguish this new species from the other species. ❑ *Decapoda, Caridea, Philocheras, Queensland.*

T. Komai, Natural History Museum and Institute, Chiba, 955-2 Aoba-cho, Chuo-ku, Chiba 260-8682, Japan (e-mail: komai@chiba-muse.or.jp); 21 February 2004.

Philocheras Stebbing, 1900 is the most speciose genus in the Crangonidae, represented by about 50 species worldwide. It is widespread in tropical to temperate waters, although poorly represented in the eastern Pacific and western Atlantic (Chace, 1984). The genus had long been treated as junior synonym of *Pontophilus* Leach, 1817 since Kemp (1911), but Chace (1984) reinstated *Philocheras as* a valid genus. Christoffersen's (1988) phylogenetic analysis of the Crangonidae also supports the generic status of *Philocheras. Philocheras is* characterized by the usual lack of lateral teeth on the rostrum, the transversely oblong stylocerite of the antennule, first pereiopod without exopod, and second pereiopod usually overreaching the extended merus of the first pereiopod. Seven species are known from Australia: *P. flindersi* (Fulton & Grant, 1902) from Victoria; *P. intermedius* (Bate, 1863) from the Gulf of St Vincent; *P. lowisi* (Kemp, 1916) from the Timor Sea; *P. obliquus* (Fulton & Grant, 1902) from Victoria; *P. pilosus* (Kemp, 1916); *P. planoculminus* Bruce, 1994 from the Timor Sea; and *P. victoriensis* (Fulton & Grant, 1902) from Victoria.

Specimens of small crangonid shrimp collected during the surveys of inshore waters of northern Queensland, were submitted to the author for identi ication by Alexander J. Bruce of the Queensland Museum. Close examination revealed that these specimens represent a new species of *Philocheras*, here described as *P. brucei.* The new species is compared with *P. angustirostris* (De Man, 1918), *P. incisus* (Kemp, 1916), *P. kempi* (De Man, 1918), *P. parasculptus* Burukovsky, 1991, *P. sculptus* (Bell, 1847) and *P. vanderbilti* (Boone, 1935).

The type specimens are deposited in the Queensland Museum (QM). CL refers to the postorbital carapace length.

SYSTEMATICS

Order DECAPODA
Family CRANGONIDAE
Genus **Philocher**as Stebbing, 1900

Philocheras brucei sp. nov.
(Figs 1-4)

ETYMOLOGY It is my pleasure to dedicate this new species to Dr Alexander J. Bruce in recognition of his great contributions to the systematics of decapod crustaceans, particularly carideans in the Indo-Pacific.

MATERIAL. Holotype: 1 ♂ (CL 2.6mm), Cairns, northeast Queensland, 16°55'S, 145°46'E, 10m, beam trawl, shot 467,19 November 2001, coll. K. Neil, QMW26737a. Paratypes: 3 ♂♂ (CL 1.8-2.2mm), 4 non-ovigerous ♀♀ (CL 1.6-2.1mm), 1 ovigerous ♀ (CL 2.9mm), similar locality as holotype, beam trawl, shot 508, coll. K. Neil, QMW26736; 3 ♂♂ (CL 2.2-3.0mm), 2 non-ovigerous ♀♀ (CL 2.3, 2.5mm), 1 ovigerous ♀ (CL 2.9mm), same data as holotype, QMW26737b.

DESCRIPTION. Body (Fig. 1) moderately stout for genus. Rostrum (Fig. 2A-C) narrow, falling slightly short of or reaching distal margins of eyes, slightly upturned distally, gradually tapering to truncated tip; anterior surface of truncated tip nearly flattened or slightly concave, lacking deflexed terminal lobe, circular in anterior view (Fig. 2C, inset); dorsal surface shallowly sulcate; lateral margins unarmed, with row of long setae extending onto orbital margin, covering corneal surface; ventral margin sharply carinate. Carapace (Figs 1, 2A) slightly longer than broad postorbitally, covered with short pubescence, shallowly depressed areas with

dense, longer setae; shallow, broad transverse furrow posterior to rostral base; median carina low, extending to 0.80-0.85 length of carapace, terminating in small, sharp gastric tooth at 0.15-0.16 of carapace length, smooth or faintly tuberculate on dorsal margin, but without distinct tooth other than gastric tooth; postorbital carina low, interrupted, occasionally obsolete; anterior section not connected with rostral lateral margin, terminating anteriorly in small acute tooth at level of gastric tooth, posterior section extending nearly to posterodorsal margin of carapace; hepatic tooth arising slightly posterior to level of orbital margin, supported by low ridge; branchial carina very low, occasionally rudimentary, if discernible, beginning from somewhat posterior to hepatic tooth to level of posterodorsal margin of carapace; orbital margin concave, without cleft; antennal tooth small; branchiostegal tooth moderately long, reaching dorsodistal margin of antennal basicerite; pterygostomian tooth tiny.

Thoracic sternum (Fig. 2D,E) widened posteriorly, with long median spur on fourth sternite far overreaching coxae of second pereiopod; in males (Fig. 2D) and non-spawning females, sternal surface convex with transverse sutures or furrows indicating fifth to eighth somites clearly discernible, sixth to eighth sternites each with sharp median tooth; in males, each sternite with transverse row of setae; in spawning females (Fig. 2E), sternal surface concave, sutures or furrows indicating somites indistinct, median teeth on sixth to eighth somites completely reduced.

Third maxilliped with 1 small arthrobranch; pleurobranchs present on fourth through eighth thoracic somites, ventral apices all directed posteriorly.

Abdomen (Fig. 1) sculptured by complex pattern of shallow transverse grooves or depressions and low carinae on first to fifth somites; grooves covered with short setae, but carinae or elevated parts naked. First somite with faint median carina connected with posterodorsal carina. Second somite also with faint median carina interrupting transverse groove. Third and fourth somites with low, distinctly delimited median carinae occasionally connected with transverse carinae. Fifth somites with paired median carinae divided by shallow longitudinal groove widened posteriorly. Sixth somite with low, broad median carina bearing shallow occasionally paired depressions on either side of midline. Pleura of first to fifth somites each with small to large patches of short setae; ventral

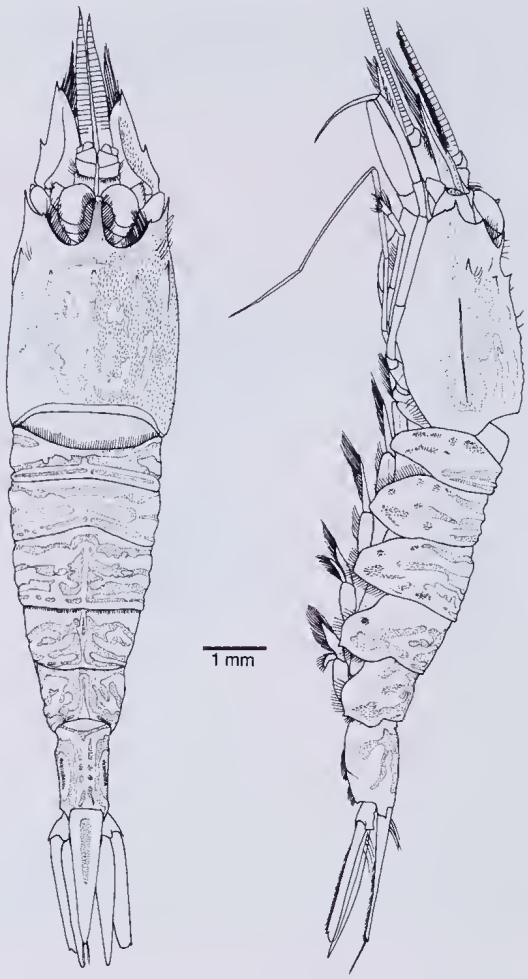

FIG. 1. *Philocheras brucei* sp. nov. Entire animal in lateral and dorsal views (fifth pereopod missing). Holotype, ♂ (CL 2.6mm; QMW26737a).

margin rounded or slightly angular in first to third somites; pleuron of fourth somite sinuous on anteroventral margin, convex on posterolateral margin, with subacute posteroventral tooth; pleuron of fifth somite sinuous on both anteroventral and posteroventral margins, with small posteroventral tooth. Sixth somite about 1.60 × longer than fifth somite and 1.50 × longer than greatest height; ventral surface with thick assemblage of long setae on either side of V-shaped median depression. Telson (Fig. 2G) moderately narrow, about 1.60 × longer than sixth somite, tapering posteriorly and terminating in small triangular projection; dorsal surface with shallow median sulcus filled with short setae in

anterior half, lacking dorsolateral spines; lateral margin with broad, very low convexity subproximally; posteromedian projection (Fig. 2H) flanked by 1 pair of long spiniform setae and 1 pair of plumose setae slightly longer than spiniform setae.

First to fifth abdominal sternites each with blunt median tubercle becoming smaller toward posterior in males and non-spawning females; median tubercles completely reduced in spawning females.

Cornea of eye (Figs 1, 2A) placed anterodorsally on eye-stalk, darkly pigmented and well faceted, maximum diameter 0.25-0.30 of carapace length. Eye-stalk lacking dorsal tubercle.

Antennular peduncle (Figs 1, 2A) reaching midlength of antennal scale in males, falling short of it in females, stouter in males than in females. First segment longer than distal two segments combined, dorsal surface strongly concave to accommodate eye, bearing oblique row of setae; ventromesial ridge with small tooth medially; stylocerite subquadrate with anterolateral angle weakly produced anteriorly, rounded, and posterolateral margin bluntly angular. Second segment wider than long, with slightly produced anterolateral angle. Third segment as wide as second segment in males, somewhat narrower than it in females. Lateral flagellum overreaching distal margin of lamella of antennal scale by half length in males, 0.20-0.25 length in females, much stouter in males than in females, composed of about 20 articles in males, 7-10 articles in females; mesial flagellum longer than lateral flagellum, composed of about 10 articles.

Antenna (Figs 1, 2A) with basicerite stout, with small ventrolateral tooth. Carpocerite stout, overreaching midlength of antennal scale. Antennal scale narrowed distally; dorsal surface with covering of short setae except for strongly concave median ridge; lateral margin armed with large tooth arising at about midlength, margin proximal to lateral tooth slightly concave or sinuous, margin distal to lateral tooth nearly straight; distolateral tooth large, far overreaching narrow, obliquely rounded distal margin of blade.

Mandible (Fig. 2I) principally 3-toothed, largest tooth with small accessory tooth. Maxillule (Fig. 2J) with ovate coxal endite bearing row of setae on mesial margin; basial endite strongly curved mesially, truncate terminally, armed with 4 or 5 spines arranged in double row; palp somewhat curved, terminating in small lobe bearing 1 apical spiniform seta. Maxilla (Fig. 2K) with 2 lobes on mesial margin, possibly representing rudimentary endites, proximal lobe with few long setae; palp strongly curved mesiaiiy, with apical seta; scaphognathite with somewhat elongate, rounded posterior lobe bearing very long setae on posterior margin. First maxilliped (Fig. 2L) lacking endites; palp flattened, nearly reaching distal margin of exopod, bearing 1 very long plumose seta and some subdistal setae; exopod with narrow caridean lobe fringed with row of short setae; exopodal flagellum well developed; epipod somewhat elongate longitudinally, faintly bilobed. Second maxilliped (Fig. 2M) with endopod apparently composed of 6 segments with basis and ischium fused; dactylus and propodus with row of slender spines on mesial margin and stiff setae, dactylus with cluster of short setulose setae at terminal margin; exopod slender, slightly overreaching distal margin of carpus of flexed endopod, bearing welldeveloped flagellum; epipod subrectangular, bearing multilamellate podobranch. Third maxilliped (Fig. 3A) 4-segmented, flattened dorsoventrally, overreaching distal margin of antennal scale (except for distolateral tooth) by half length of ultimate segment; ultimate segment 1.10-1.20 longer than carpus (= penultimate segment), moderately narrow (5.5-6.0 × longer than basal width), tapering distally, mesial margin with row of long setae; carpus with short to long setae on dorsal surface and lateral margin, mesial surface with numerous transverse tracts of dense, stiff setae; antepenultimate segment (merus, ischium and basis fused segment) strongly sinuous in dorsal view, setose on margins, setae on dorsolateral distal angle particularly elongate; distal part of ventral surface with short longitudinal row of 8-10 spinules directed laterally (Fig. 3A, inset); coxa stout, with rectangular lateral process and small setose protuberance on mesial surface; exopod reaching beyond midlength of antepenultimate segment, somewhat tapering distally, bearing well-developed flagellum.

First pereiopod (Fig. 3B) stout, reaching or slightly overreaching distal margin of antennal scale; palm of subchela (Fig. 3C) not narrowed distally, moderately stout (2.90-3.10 × longer than wide), mesial surface with stiff setae or spiniform bristles proximally extending to midway between base of palm and base of pollex; cutting edge strongly oblique, with submarginal

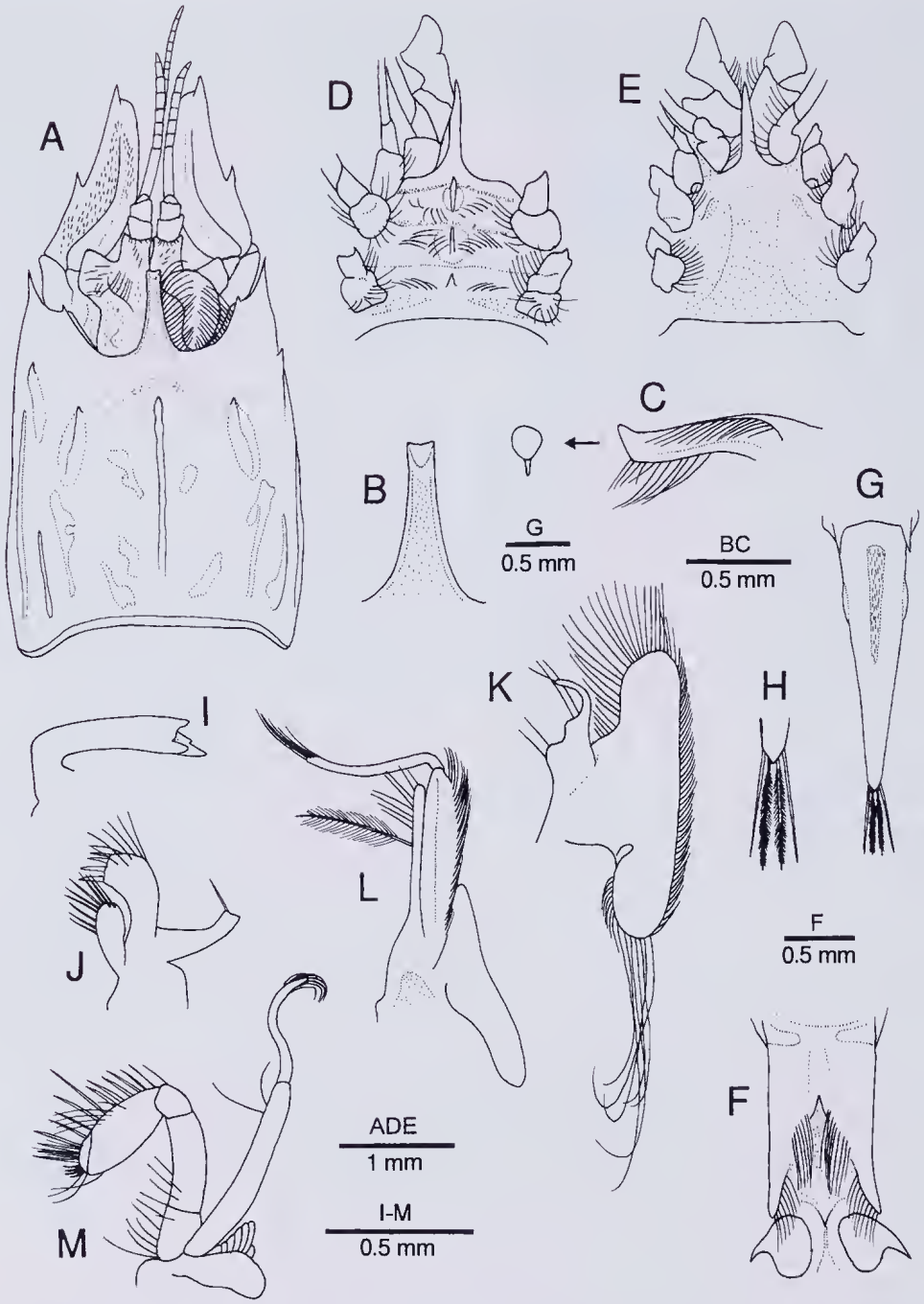

FIG. 2. *Philocheras brucei* sp. nov. A, carapace and cephalic appendages, dorsal view; B, rostrum, dorsal view; C, same, lateral view; inset, anterior surface of rostrum, anterior view; D, E, thoracic sternum, ventral view; F, sixth abdominal somite, ventral view; G, telson, dorsal view, H, posterior part of telson, dorsal view; I, left mandible, dorsal view; J, left maxillule, ventral view; K, left maxilla, ventral view; L, left first maxilliped, ventral view; M, left second maxilliped, ventral view. A-C, E, paratype ovigerous ♀ (CL 2.9mm; QMW26737b); D, F, G, H, holotype, ♂ (CL 2.6mm; QMW26737a); I-M, paratype, ♀ (CL 2.1mm; QMW26736).

row of short setae dorsally and ventrally; pollex basally articulated, straight or slightly recurved; carpus short, with small ventrodistal tooth on lateral margin and cluster of stiff setae on mesial surface; dactylus about half length of palm; merus strongly compressed laterally, with small dorsodistal tooth, but unarmed on dorsolateral margin; ventral margin of merus somewhat sinuous. Second pereiopod (Fig. 3D) reaching distal margin of carpus of anteriorly extended first pereiopod, chelate; dactylus subequal in length to palm, with long, setulose unguis; chela shorter than carpus, pollex also with long, setulose unguis; carpus shorter than merus, with 2 long spiniform setae at ventrodistal angle; ischium and merus with row of long plumose setae on dorsal margin and row of long spiniform setae on ventral margin. Third pereiopod (Fig. 3E) very slender, overreaching distal margin of antennal scale by length of dactylus, propodus and 0.50-0.60 of carpus length; dactylus about 0.70 × as long as propodus, terminating in acute tip; carpus elongate, longer than distal two segments combined or merus; merus slightly longer than ischium; ischium with row of setae on dorsal margin; coxa stout, setose, but lacking lateral projection. Fourth pereiopod (Fig. 3F) moderately slender for genus, overreaching distal margin of scaphocerite by length of dactylus; dactylus about 0.90 × of propodus length, slender, weakly curved, weakly flattened dorsoventrally, terminating acutely; ventral surface of dactylus medially ridged in proximal half; propodus with row of setae on dorsal surface; carpus 0.37-0.40 × as long as propodus; merus and ischium with row of setae on dorsal and ventral surfaces (dorsal setae longer than ventral setae), merus 1.80-1.90 × longer than ischium and 9.0-10.0 × longer than height. Fifth pereiopod (Fig. 3G) similar to fourth pereiopod, but slightly shorter and less setose; dactylus 0.80-0.90 × as long as propodus.

Pleopods of males (Fig. 4A,B,D-F) with stout protopods somewhat widened distally.

Endopod of first pleopod (Fig. 4A) about half length of exopod, tapering distally to blunt tip, with row of setae becoming spiniform distally; endopods of second to fifth pereiopods (Fig. 4B-F) 0.50-0.60 length of exopods, each with stout appendix internae; appendices internae each with minute cincinnuli. Appendix masculina on second pleopod (Fig. 4C) stout, distinctly longer than appendix interna, but not reaching tip of endopod, armed with several long spiniform setae on rounded, subtruncate distal portion.

Pleopods in spawning females (Fig. 4G-K) with less stout protopods (about half as wide as those of males); exopod articulated perpendicular to horizontal plane of protopod. Endopod of first pleopod (Fig. 4G) about 0.60 length of exopod, not tapering distally with rounded distal margin, bearing row of setae on margins; endopod of second pleopod (Fig. 4H) 0.50-0.60 length of exopod; endopod of third pleopod (Fig. 4I) about half length of exopod; endopod of fourth pleopod (Fig. 4J) nearly straight, about 0.40 length of exopod, with sparse marginal setae; endopod of fifth pleopod (Fig. 4K) reduced, subtriangular, with some marginal setae. Appendices internae becoming smaller posteriorly, all lacking cincinnuli, but with few long setae; fifth pleopod lacking appendix interna.

Pleopods in non-spawning females with endopods relatively smaller than those of spawning molts; appendices internae lacking cincinnuli or long setae.

Uropod (Fig. 1) with both rami distinctly overreaching tip of telson. Endopod narrow, tapering distally. Exopod shorter than endopod, lacking diaeresis; lateral margin nearly straight, terminating in small tooth far falling short of rounded posterior margin o lamella.

COLOURATION. Unknown.

SIZE. Males 1.8-3.3mm; females 1.6-2.9mm, ovigerous individuals 2.9mm.

DISTRIBUTION. Cairns, Queensland; 10m.

REMARKS. *Phidochetas brucei* sp. nov. has a distinct lateral tooth on the antennal scale. The following 6 species of *Philocheras* also possess a single lateral tooth on the antennal scale: *P. angustirostris* (De Man, 1918); *P. incisus* (Kemp, 1911); *P. kempi* (De Man, 1918); *P. parasculptus* Burukovsky, 1992; *P. sculptus* (Bell, 1847); and *P. vanderbilti* (Boone, 1935). Differences between these species and *P. brucei* are discussed below.

Philocheras angustirostris differs from *P. brucei* having 3 lateral teeth on the carapace (De Man, 1920), rather than 2 teeth in the latter. The middorsal carina is interrupted in *P. angustirostris*, rather than entire in *P. brucei* sp. nov. The merus of the first pereiopod is armed with 3 tiny teeth on the distolateral margin in *P. angustirostris*, while that margin is unarmed in *P.*

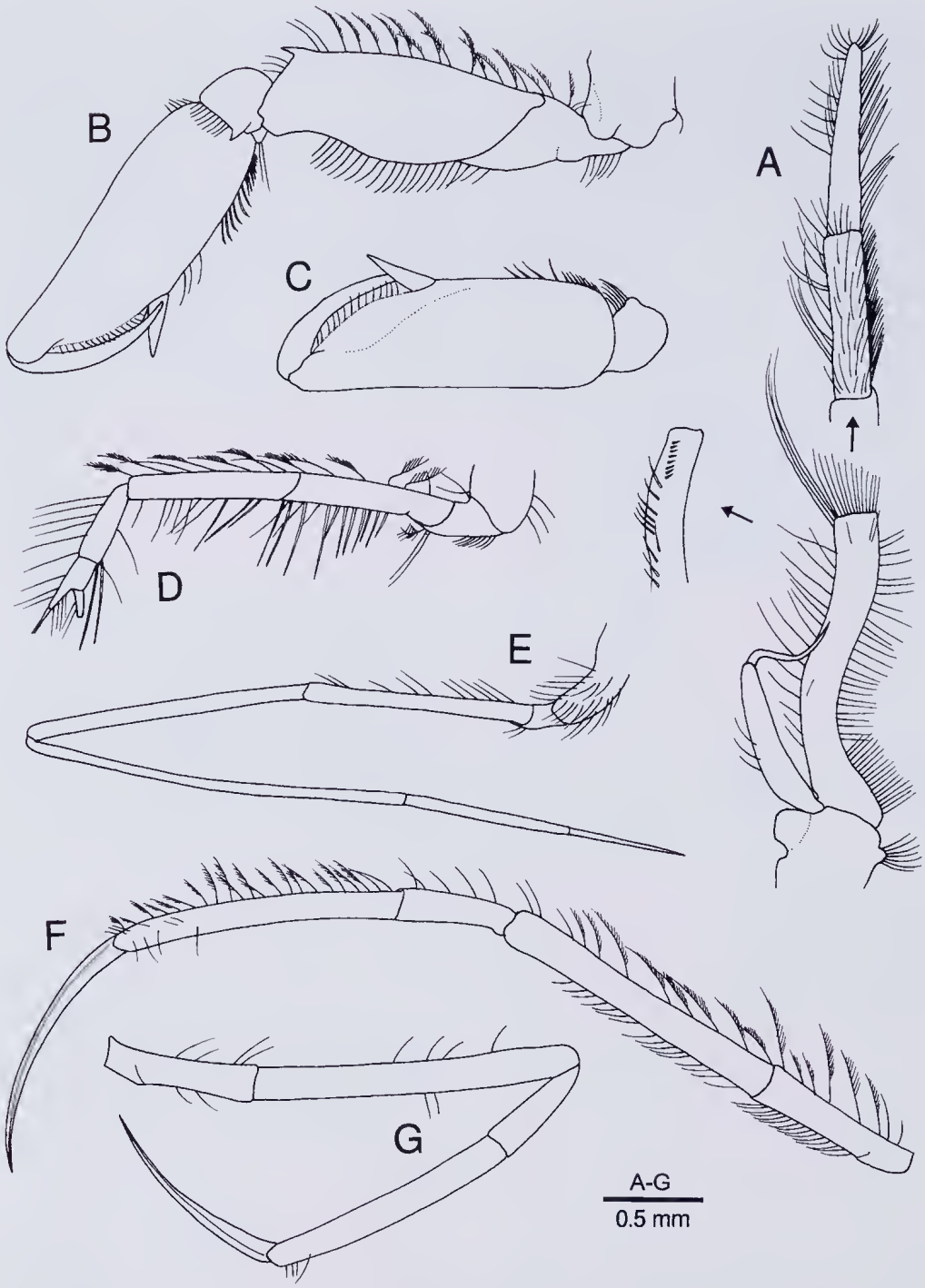

FIG. 3. *Philocheras brucei* sp. nov. A, left third maxilliped, dorsal view; inset distal part of antepenultimate segment, ventral view; B, left first pereiopod, lateral view; C, same, subchela, dorsal view; D, left second pereiopod, lateral view; E, left third pereiopod, lateral view; F, left fourth pereiopod, lateral view; G, right fifth pereiopod, lateral view. Holotype, male (CL 2.6mm; QMW26737a).

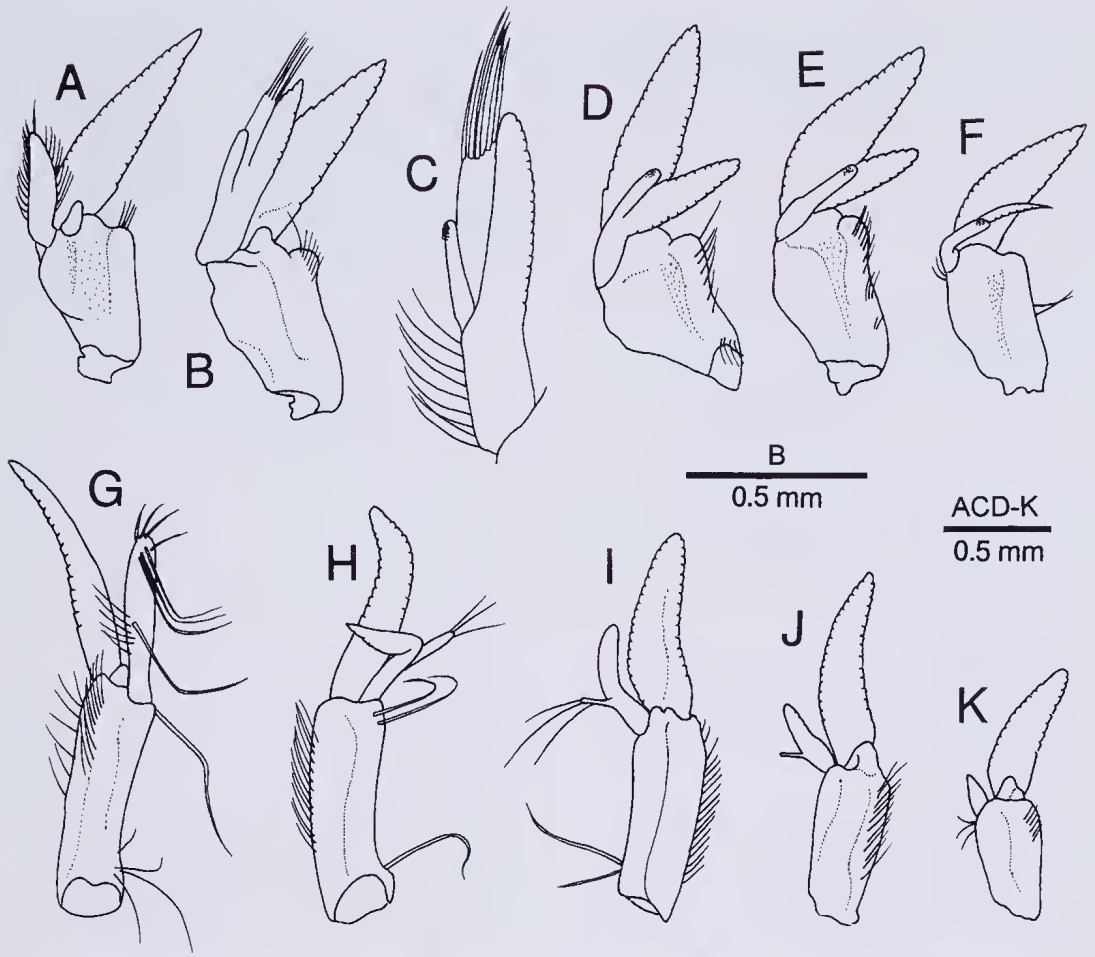

FIG. 4. *Philocheras brucei* sp. nov. Left pleopods. A, G, first pleopods (A, ventral view; G, dorsal view); B, H, second pleopods (B, ventral view; H, dorsal view); C, appendix masculina and appendix interna of second pleopod; D, I, third pleopods, ventral view; E, J, fourth pleopods, ventral view; F, K, fifth pleopods, ventral view. A-F, holotype, ♂ (CL 2.6mm; QMW26737a); G-K, paratype, ovigerous ♀ (CL 2.9mm; QMW26737b).

brucei sp. nov. *Philocheras angustirostris* is known from the Arabian Sea, Bay of Bengal and Indonesia, at depths of 13-83m (Chace, 1984). *Philocheras incisus* is easily separated from *P. brucei* by the distinctly broader-rostrum with a distinctly concavc anterior margin and with a terminal lobe abruptly deflexcd into a vertical plane, by the distinct lateral carinae on the carapace subdivided in short lobes and by the sharp tooth posterior to the hepatic tooth. The lateral tooth on the antennal scale arises usually subproximally in *P. incisus*, rather than arising from about the midlength in *P. brucei* sp. nov. The median carina on the third abdominal somite is distinctly higher in *P. incisus* than in *P. brucei* sp. nov. *Philocheras incisus* is widely distributed in the Indo-West Pacific region, including the Arabian Sea, Bay of Bengal, Indonesia, Philippines, East China Sea and southern Japan, at depths of 3-110 m (Chace, 1984).

Philocheras kempi is readily distinguished from *P. brucei* the possession of a sharp tooth posterior to the hepatic tooth, the absence of a distal blade on the antennal scale, and the fixed pollex of the first pereiopod (De Man, 1920). *Philocheras kempi is* known only by the type material taken in the Flores Sea, Indonesia, at depths of 300-400m (Chace, 1984).

Philocheras parasculptus and *P. sculptus*. These two species are immediately distinguished

from *P. brucei* sp. nov. by the much broader rostrum widened distally, the second middorsal tooth and of a sharp tooth posterior to the hepatic tooth on the carapace, and the high median carina on the third abdominal somite (Kemp, 1910; Crosnier & Forest, 1973; Burukovsky, 1991). *Philocheras parasculptus* is represented only by the holotype from the SW Indian Ocean (33°16'S, 43°53'E), at depths of 415-460 m (Burukovsky, 1991). *Philocheras sculptus* is widely distributed in the W Atlantic and the Mediterranean, ranging from intertidal to 400 m (Udekem d'Acoz, 1999).

Philocheras vanderbilti differs from *P. brucei* by its much broader rostrum with a distinctly concave anterior margin, 3 middorsal teeth, 3 lateral teeth, and non-sculptured abdomen (Boone, 1935). *Philocheras vanderbilti* is known only by the holotype from the Lesser Sunda Islands, Indonesia, at a depth of 256m (Chace, 1984).

After Kemp (1911) synonymised *Philocheras* with *Pontophilus*, Kemp (1916) divided the genus into 5 groups on the development of the endopods and appendices internae of pleopods. One of these groups (Group I) corresponds to *Pontophilus* and *Parapontophilus* Christoffersen, 1988, leaving the other 4 groups in *Philocheras*. De Grave (2000) remarked, however, that pleopodal development is varied within *Philocheras* and cannot be used to indicate intrageneric relationships. Indeed, *Philocheras brucei* and *P. angustirostris*, present a further type of pleopodal development with well-developed endopods on the pleopods 1-4 and a well-developed appendix interna on pleopod 2 and somewhat reduced appendices internae on pleopods 3-4 in the female. Among the other species compared with *P. brucei, P. incisus* and *P. sculptus* were referred to Group II (Kemp, 1916).

Pleopodal development is poorly understood for *P. kempi*, *P. parasculptus* and *P. vanderbilti*. Although the highly variable pleopodal development in the genus is remarkable, its ecological significance remains unclear.

The new species brings the number known in Australian waters of this genus to 8.

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LITERATURE CITED

BATE, C.S. 1863. On some new Australian species of Crustacea. Proceedings of the Zoological Society of London 1863: 498-505.

BELL, T. 1844-1853. A history of the British stalk-eyed Crustacea. (John Van Voorst: London).

BOONE, L. 1935. Crustacea: Anomura, Macrura, Euphausiacea, Isopoda, Amphipoda and Echinodermata: Asteroidea and Echinoidea. Scientific results of the world cruise of the yacht "Alva," 1931, William K. Vanderbilt, commanding. Bulletin of the Vanderbilt Marine Museum 6: 1-264.

BRUCE, A.J. 1994. Shrimps from Flat-top Bank, Timor Sea (Crustacea: Decapoda: Caridea). Raffles Bulletin of Zoology 42: 743-756.

BURUKOVSKY, R.N. 1991. New and rare species of shrimps from the south-east part of the Indian Ocean. Zoologicheskii Zhurnal 70: 36-41 (In Russian).

CHACE, 1984. Caridean shrimps (Crustacea: Decapoda) of the Albatross Philippine Expedition 1907-1910, part 3: Families Thalassocarididae and Pandalidae. Smithsonian Contributions to Zoology 411: i-iv, 1-143.

CHRISTOFFERSEN, M.L. 1988. Genealogy and phylogenetic classification of the world Crangonidae (Crustacea, Caridea), with a new species and new records for the south western Atlantic. Revista Nordestina de Biologia 6: 43-59.

CROSNIER, A. & FOREST, J. 1973. Les crevettes profondes de l'Atlantique oriental tropical. Faune Tropicale, ORSTOM 19:1-409.

DAVIE, P.J.F. 2002. Crustacea: Malacostraca: Phyllocarida, Hoplocarida, Eucarida (Part 1). Pp. xii, 551. In Wells, A. & Houston, W. W. K. (eds) Zoological catalogue of Australia, 19.3A. (CSIRO Publishing: Melbourne).

DE GRAVE, S. 2000. A new *Philocheras* species (Decapoda, Crangonidae) from Hansa Bay, Papua New Guinea. Hydrobiologia 432: 49-56.

FULTON, S.W. & GRANT, F.E. 1902. Some little known Victorian decapod Crustacea with descriptions of new species II. Proceedings of the Royal Society of Victoria 15: 59-68, pls. 8-10.

KEMP, S. 1910. The Decapoda Natantia of the coasts of Ireland. Scientific Investigations 1908, 1. Pp. 1-190, pls. 1-23. (Fisheries Branch, Department of Agriculture for Ireland).

1911. Notes on Decapoda in the Indian Museum, II: Descriptions of two new Crangonidae with observations on the mutual affinities of the genera *Pontophilus* and Philocheras. Records of the Indian Museum 6: 5-12.

1916. Notes on Crustacea Decapoda in the Indian Museum, VI: Indian Crangonidae. Records of the Indian Museum 12: 355-384.

LEACH, W.E. 1817. Malacostraca Podophthalma Britanniae; or descriptions of the British species of crabs, lobsters, prawns, and of other malacostraca

with pedunculated eyes. (Arding & Merret: London).

MAN, J.G. de 1918. Diagnosis of new species of macrurous decapod Crustacea from the Siboga-Expedition. Zoologische Medcdeelingen 4: 159-166.

1920. The Decapoda of the Siboga Expedition. IV Families Pasiphaeidae, Stylodactylidae, Hoplophoridae, Nematocarcinidae, Thalassocaridae, Pandalidae, Psalidopodidae, Gnathophyllidae, Processidae, Glyphocrangonidae, and Crangonidae. Siboga Expeditie, Monographie $39a^{8}$: 1-318.

STEBBING, T.R.R. 1900. South African Crustacea, part 1. Marine Investigations in South Africa 1: 14-66.

UDEKEM-D'ACOZ, C. D'. 1999. Inventaire et distribution des crustaces decapodes de l'Atlatinque nord-oriental, de la M6diterranee et des eaux continentales adjacentes au nord de 25°N. Collection Patrimoines Naturels 40: 1-383.

COMMENSALS ON NESTING HAWKSBILL TURTLES (*ERETMOCHELYS IMBRICATA*), MILMAN ISLAND, NORTHERN GREAT BARRIER REEF, AUSTRALIA. *Memoirs of the Queensland Museum 49(2): 674. 2004:-* Sea turtles carry a large array of commensals (Frazier et al., 1985; et al., 1991; et al., 1992; Hollenberg & Norris, 1977; Monroe & Limpus, 1979) that are often overlooked. Witzell (1983) noted the incomplete commensal data set for hawksbill turtles (*Eretmochelys imbricata*). Studies of hawksbill turtle nesting patterns and behaviours at Milman Island (Dobbs et al., 1999; Loop, 1996; Loop et al., 1995) allowed collection of commensals during summers January 1991- February 1995.

Commensals were found on 88% (n=1225) of 1392 nesting hawksbill turtles. The most frequent commensal was the barnacle *Chelonibia caretta*, found on the carapace, plastron or head of 1123 turtles (81%); egg-bearing *C. caretta* were observed December 1994 - February 1995. *Balanus* sp. (carapace) and *Platylepas* sp. (skin) were other barnacles randomly noted on nesting hawksbills. The burrowing barnacle *Tubicinella cheloniae* was found in the carapace of 30% of nesting turtles (n=422). Barnacles were encountered at all locations on the carapace. No consistent barnacle attachment pattern was noted. On some turtles, *Tubicinella cheloniae* covered up to 75% of the carapace, while some burrowed through the edge of marginal scutes.

Filamentous algae occurred on 47% (n=649) of nesting turtles. *Gelidiopsis intricata*, *Gelidiella pannosa* and *Polysiphonia* sp. were identified. Nongeniculate corallinaceae (encrusting algae) was found on the carapace or on attached barnacles of 18 turtles (1.3%). Algae was encountered everywhere on the carapace and predominantly under the trailing edge of the last vertebral and costal scutes.

Ozobranchus sp. leeches occurred around the cloaca, attached to the underside of front flippers, around a crater wound or on the face of 25 hawksbills (1.8%). The only period during which leech eggs were recorded was January - April 1993. The eggs were on the posterior ventral end of the carapace and on the plastron of nesting turtles. Marine worms (Cirratulidae, Eunicidae, Nereididae) occurred on 18 turtles (1.3%). Other items on the carapaces included a vermetid gastropod (2 turtles), marine crabs (4 turtles), Ophiurid brittlestars (2 turtles), half of an oyster shell (1 turtle), mud (2 turtles) and amphipods.

Commensals on most hawksbills at Milman Island were similar to those noted by Limpus et al., (1983) who reported 100% of their nesting conspecifics had commensal barnacles. Diamond (1976), Pritchard (1969) and Ross (1981) found most hawksbill turtles nesting at Cousin Island, Seychelles, Guyana and Oman, respectively, had large barnacles on their carapaces. Vaughan (1981) reported commensals from 55% of Solomon Island hawksbills. All species of barnacle recorded on hawksbills herein had been reported by Monroe & Limpus (1979).

Hawksbill turtles range over a variety of habitats and may migrate long distances between foraging and nesting areas (Miller et al., 1998; Parmenter, 1983; Vaughan & Spring, 1980). Their preferred foraging habitats commonly include rocky areas, coral reefs, lagoons, bays and estuaries in the circumtropical Atlantic, Indian and Pacific Oceans (Witzell 1983). Terrigenous material, found here on 2 turtles and on 1 at Campbell Island (Limpus et al., 1983) indicates migration from inshore waters where mud may have been encountered whist foraging. Coral reefs that surround most hawksbill nesting beaches (Witzell, 1983) do not contain mud.

An in-depth analysis of sea turtle commensals, their biology and distribution should provide new insights on habitats in which they have lived. Careful collection and identification of organisms living in association with the epibiotic communities require further attention. Sadly specimens collected during this study were lost during a flood.

Acknowledgements

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Literature Cited

DIAMOND, A.W. 1976. Breeding biology and conservation of hawksbill turtles, *Eretmochelys imbricata* L., on Cousin Island, Seychelles. Biological Conservation 9: 199-215.

DOBBS, K.A., MILLER, J.D., LIMPUS, C.J. & LANDRY, A.M., JR. 1999. Hawksbill turtle, *Eretmochelys imbricata*, nesting at Milman Island, northern Great Barrier Reef, Australia. Chelonian Conservation and Biology 3(2): 344-361.

FRAZIER, J.G., GOODBODY, I. & RUCKDESCHEL, C.A. 1991. Epizoan communities on marine turtles: II. tunicates. Bulletin of Marine Science 48: 763-765.

FRAZIER, J., MARGARITOULIS, D., MULDOON, K., POTTER, C.W., ROSEWATER, J., RUCKDESCHEL, C. & SALAS, S. 1985. Epizoan communities on marine turtles I. bivalve and gastropod molluscs. Marine Ecology 6: 127-140.

FRAZIER, J., WINSTON, J.E. & RUCKDESCHEL, C.A. 1992. Epizoan communities on marine turtles; III. bryozoa. Bulletin of Marine Science 51: 1-8.

HOLLENBERG, G.J. & NORRIS, J.N. 1977. The red algae Polysiphonia (Rhodomelaceae) in the northern Gulf of California. Smithsonian Contributions in Marine Science, 1.

LIMPUS, C.J., MILLER, J.D., BAKER, V. & MCLACHLAN, E. 1983. The hawksbill turtle, *Eretmochelys imbricata* (L.), in North-eastern Australia: the Campbell Island rookery. Australian Wildlife Research 10: 185-197.

LOOP, K.A. 1996. Hawksbill turtle (*Eretmochelys imbricata*) nesting at Milman Island, Queensland, Australia. Unpubl. PhD dissertation, Texas A&M University, Department of Wildlife and Fisheries Sciences, College Station, Texas USA.

LOOP, K.A., MILLER, J.D. & LIMPUS, C.J. 1995. Nesting by the hawksbill turtle (*Eretmochelys imbricata*) on Milman Island, Northern Great Barrier Reef, Australia. Wildlife Research 22: 241-252.

MILLER, J.D., DOBBS, K.A., MATTOCKS, N., LIMPUS, C.J. & LANDRY, A.M., JR 1998. Long distance migrations by the hawksbill turtle (*Eretmochelys imbricata*) from Eastern Australia. Wildlife Research 25: 89-95.

MONROE, R. & LIMPUS, C.J. 1979. Barnacles on turtles in Queensland waters with descriptions of three new species. Memoirs of the Queensland Museum 19: 197-223.

PARMENTER, C.J. 1983. Reproductive migration in the hawksbill turtle (*Eretmochelys imbricata*). Copeia 1983: 271-3.

PRITCHARD, P. 1969. Sea turtles of the Guianas. Bulletin of the Florida State Museum 13: 85-140.

ROSS, J.P. 1981. Hawksbill turtle *Eretmochelys imbricata* nesting in the Sultanate of Oman. Biological Conservation 19: 99-106.

VAUGHAN, P. 1981. Marine turtles: a review of their status and management in the Solomon Islands. (Ministry of Natural Resources, Fisheries Division: Honiara, Solomon Islands).

VAUGHAN, P. & SPRING, S. 1980. Long distance hawksbill recovery. Marine Turtle Newsletter 16: 6-7.

WITZELL, W.N. 1983. Synopsis of biological data on the hawksbill turtle, *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fisheries Synopsis 137.1.

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LIOCHELES LITODACTYLUS (SCORPIONES: LIOCHELIDAE): AN UNUSUAL NEW *LIOCHELES* SPECIES FROM THE AUSTRALIAN WET TROPICS (QUEENSLAND)

LIONEL MONOD AND ERICH S. VOLSCHENK

Monod, L. & Volschenk, E.S. 2004 06 30: *Liocheles litodactylus* (Scorpiones: Liochelidae): an unusual new *Liocheles* species from the Australian Wet Tropics (Queensland). *Memoirs of the Queensland Museum* **49**(2): 675-690. Brisbane. ISSN 0079-8835.

A new scorpion species, *Liocheles litodactylus*, is described from the Thornton Uplands, a small mountainous massif of Far North Queensland, Australia. This species differs most notably from all other species of the genus by the absence of a lobe on the movable pedipalp finger and of a corresponding notch on the fixed finger in both males and females. Comments concerning the taxonomic value of this feature within Liochelidae are given. *Liocheles litodactylus* is the first Australian scorpion that can be considered to be a short range endemic species and additional notes are given on the probable mechanism by which this species evolved. ❑ *Liocheles litodactylus, Liochelidae, Scorpiones, endemic, Wet Tropics, Queensland.*

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In a landmark revision of the Australo-Papuan scorpion fauna, Koch (1977) recognised 3 species in *Liocheles*: *L. australasiae* (Fabricius, 1775), *L. karschii* (Keyserling, 1885) and *L. waigiensis* (Gervais, 1843). Additions to the Australian fauna since then are *Liocheles extensus* Locket, 1995 (Locket, 1997) from Kakadu National Park (Northern Territory) and *Liocheles polisorum* Volschenk et al., 2001, the only known cave-adapted species in the family, from limestone caves of Christmas Island (Indian Ocean).

Liocheles australasiae is widely distributed from India to the western Pacific Islands and can be easily distinguished from all other Australian *Liocheles* by its trichobothriotaxy (Fig. 1): the trichobothrium *Esb* is positioned basally, close to the *Eb* group, whereas in the *L. waigiensis* group, it is located more distally, closer to *Est*. The wide distributional range of *L. australasiae* is significant in that it crosses Wallace's Line (and all other noted biogeographical lines in the Indopacific region), an impressive distribution considering the relatively low vagility of scorpions. The ability for this species to disperse and colonise islands in the region has been documented by its appearance on Sertung (Vachon & Abe, 1988), an island remnant of the Krakatau Island (a volcano), destroyed and fragmented during its eruption in 1883. In 1952 Anak Krakatau, the new volcanic cone of former Krakatau, erupted violently and is thought to have eliminated any previously existing scorpion populations on the island group (Vachon & Abe, 1988). Surveys conducted prior to the 1952 eruption of Anak Krakatau, in 1908 (Jacobson, 1909) and 1933 (Kopstein, 1935), did not find *L. australasiae*. The population reported by Vachon & Abe (1988) can therefore be attributed to a recent colonisation event.

Liocheles waigiensis, the most commonly encountered species in Australia, is widely distributed in tropical and subtropical forests along the north-eastern coast (Queensland and the north of New South Wales). *Liocheles waigiensis* is also reported from rainforest patches in the Northern Territory and even in relictual rainforest patches of the Kimberley region of Western Australia. This species was considered polymorphic by Koch (1977). However, Monod (2000) indicated that several morphologically discrete forms are included under *L. waigiensis* and the species is likely to be subject to splitting in the future.

In Australia *L. karschii* is confined to Cape York Peninsula and to various islands in the Torres Strait, but it also occurs in southern New Guinea (Koch, 1977; Seymour et al., 1995).

An ongoing revision of all *Liocheles* species indicates that *L. waigiensis*, formerly considered as polymorphic (Koch, 1977), is composed of several distinct species. In this contribution, we describe *L. litodactylus*, a new species from the Queensland Wet Tropics.

Mature males of *Liocheles* typically possess an apophysis on the movable chela finger, whereas juveniles and females do not. *Liocheles litodactylus* shows a feature unique among the known *Liocheles*

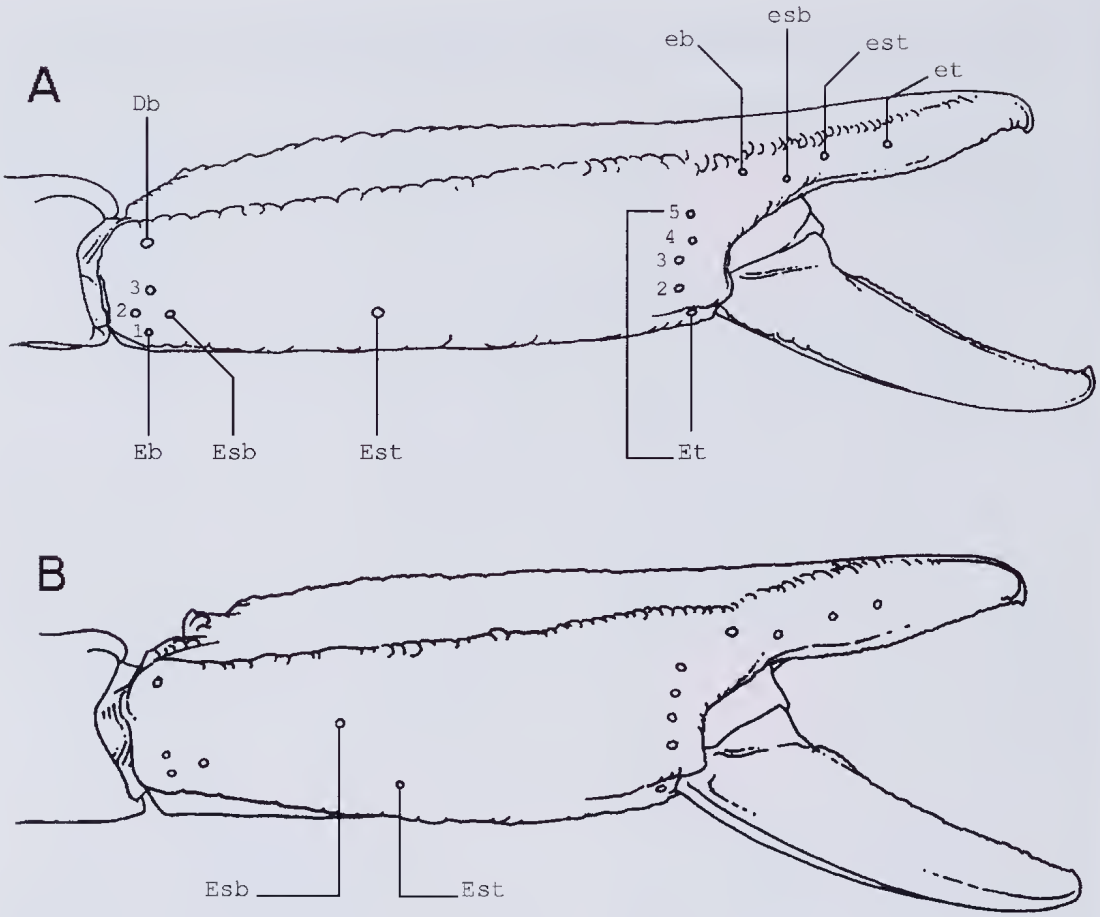


FIG. 1. Trichobothriotaxy of the external face of the pedipalp chela: A, *Liocheles australasiae*; B, *Liocheles waigiensis*.

species: both males or females possess pedipalp fingers without any tubercular sculpturing on the dentate margins. The morphology of pedipalp fingers sculpture has previously been considered as an important phylogenetic and taxonomic feature within the family Liochelidae (Newlands & Prendini, 1997; Prendini, 2000, 2001), but this is the first case in which this character is found to be important for species determination within *Liocheles*.

MATERIAL AND METHODS

Illustrations were produce by using a Wild M5 stereomicroscope with a drawing tube. Trichobothrial notations and terminology of metasomal carination follow those of Vachon (1974), measurements follow those of Stahnke (1970) and are in mm. Additional morphological terminology mostly follows that of Hjelle (1990) and Sissom (1990), and terminology of pedipalp chelal carination follows that of Prendini (2000). Hemispermatophore terminology is modified from the terminology applied by Lamoral (1979) and the terms used here are explained in the text and in Fig. 5. A more detailed examination of hemispermatophore morphology of scorpions is currently undertaken by Volschenk (in prep). The distribution map was generated with ArcView® GIS 3.1 and maps and drawings were edited in Adobe Illustrator® 8.0.

Family LIOCHELIDAE Fet & Bechly, 2001

DIAGNOSIS. Based on Lourenço (1989) and Prendini (2000). Vesicular bulge absent; cheliceral coxae lacking scaphotrix (stridulatory setae) or trichopae (chemoreceptive lamelliform setae); pedipalp chela with trichobothrium *Dt* located medially (or approximately so) on the

manus, except in *Opisthacanthus* Peters, 1861, in which *Dt* is located proximally on the manus; *Est* located submedially on manus; *eb* on the distal end of the manus, adjacent to the articulation between movable finger and manus; leg tarsi with straight laterodistal lobes; prolateral pedal spur present, retrolateral pedal and tibial spurs absent; metasomal segments I-IV with 2 parallel ventral keels; 2 or 3 pairs of lateral eyes present.

REMARKS. Fet & Bechly (2001) proposed Liochelidae as a replacement for Ischnuridae Simon, 1879, to resolve the homonymy with the damselfly (Odonata) family Ischnuridae Fraser, 1957 (ICZN, 2003).

The distribution of Liochelidae is East Gondwanian, with most extant representatives found in Africa, Australia, India and Southeast Asia. However, the liochelid *Opisthacanthus* is found in Africa and in northern South America. This disjunct transatlantic distribution has sparked considerable interest among scorpion specialists, and has resulted in several conflicting hypotheses about the origin of these Neotropical species (Francke, 1974; Lourenço, 1989; Nenilin & Fet, 1992; Newlands, 1973). Unfortunately none of these hypotheses are based on phylogenies determined by using cladistic analyses of morphological or molecular evidence. Prendini (2000) carried out a major cladistic examination of the Scorpionoidea to test the monophyly of scorpionoid families, sub-families and their component genera. This analysis which included exemplar species of all recognised liochelid genera found weak support for all these taxa except for *Liocheles* and *Hadogenes* (Prendini, 2000: figs 2, 5, 6). It emphasised the need for a more comprehensive cladistic study, of all liochelid species to clarify relationships within Liochelidae, to establish monophyletic clades and to infer biogeographic hypotheses about the family and its members.

Liocheles Sundevall, 1833

Scorpio (*Liocheles*) Sundevall, 1833: 31. [Type species by monotypy: *Scorpio australasiae* Fabricius, 1775].

Ischnurus C.L. Koch, 1837: 37, pl. VI, fig. 69. [Type species by subsequent designation (Pocock, 1902: 364): *Ischnurus complanatus* C.L. Koch, 1837 (junior synonym of *Liocheles australasiae* (Fabricius, 1775), originally described as *Scorpio australasiae* Fabricius, 1775)] [synonymised with *Hormurus* Thorell by Pocock, 1902: 364].

Hormurus Thorell, 1876: 14. [Type species by original designation: *Ischnurus caudicula* C.L. Koch, 1867 (junior synonym of *Liocheles waigiensis* (Gervais, 1843), originally described as *Scorpio* (*Ischnurus*) *waigiensis* Gervais, 1843)] [synonymised by Karsch, 1880: 408].

Hormiops Fage, 1933: 30. [Type species by monotypy: *Hormiops davidovi* Fage, 1933] [synonymised by Prendini, 2000: 72].

DIAGNOSIS. Pectines with 4-12 teeth; dentate margin of the movable pedipalp finger with 2 parallel longitudinal rows of primary granules regularly interspersed with larger granules and without any accessory granules; ventral surface of leg tarsi with 2 ventral rows of 3-5 acuminate macrosetae, retrolateral row sometimes with one or 2 small basal spinules, ventromedian series of spinules absent; trichobothria in a type C configuration, trichobothriotaxy orthobothriotaxic or neobothriotaxic (patella with 5 trichobothria instead of 3 in *Liocheles penta* Francke & Lourenço, 1991); distal lamella of hemispermatophore 'relatively' short, generally equal in size to the trunk (basal part), with a hook located basally.

REMARKS. Species of *Liocheles*, typical inhabitants of humid and tropical to subtropical ecosystems, are widely distributed inbetween India and Australia, and throughout the Indo-Pacific and Western Pacific islands. Monod (2000) divided *Liocheles* into 2 distinct species groups, the *L. waigiensis* and *L. australasiae* species groups, on the basis of the trichobothrial pattern on the external side of their pedipalpal chela (Fig. 1).

Liocheles litodactylus sp. nov.
(Figs 2-8)

ETYMOLOGY. Greek, *litos,* plain and *daktylos,* finger; referring to the absence of a lobe on the pedipalp movable finger and of the corresponding notch on the fixed finger in males. Males of all other known *Liocheles* species possess distinctive sculptures on the dentate margins of the chela fingers.

MATERIAL EXAMINED. All known specimens are in the Queensland Museum, and were collected from the Thornton Uplands, NE Queensland, Australia (Fig. 8). HOLOTYPE. ♂, S48320, Mount Pieter Botte, 16°04'S 145°24E, 950m, 21.XI.1993, G.B. Monteith, H.A. Janetzki, L. Roberts and D.J. Cook. Paratype. S22452, 3 ♀♀: same data as holotype. S35476, 2 ♀♀ Mount Pieter Botte, 16°04'S 145°24'E, 800-900m, 9.XII.1993, G.B. Monteith. S35475, 1 ♂, 2 subadult ♂♂, 1 ♀: Roaring Meg Valley, 16°04'S 145°25'E, 720m, 22.XI.1993, G.B. Monteith, H.A. Janetzki, L. Roberts & D. Cook. Additional Material. S17171, 1 subadult ♀, Granite Outcrops, 0.5km E Mount Pieter-Botte, 780m, 5.X.1982, leg. G.B. Monteith & D. Yeates. S48321, 1 ♂, Mount Halcyon, 16°03'S 145°45'E, 870m, 22-24.XI.1993, G.B. Monteith, D. J. Cook, H.A. Janetzki & L. Roberts. S22453, 1 ♀, 2 ♂♂ subadults, 1 ♂ juvenile, same data as S48321. S35474, 3 ♂♂, 2 subadult ♂, Mount Hemmant, 16°07'S 145°25'E, 1050m, 25-27.XI.1993, G.B. Monteith, D. J. Cook, H.A. Janetzki & L. Roberts. S17194, 1 ♀: Thornton Peak, via Daintree, 200-900m, 27.IX.1984, G.B. & S.R. Monteith.

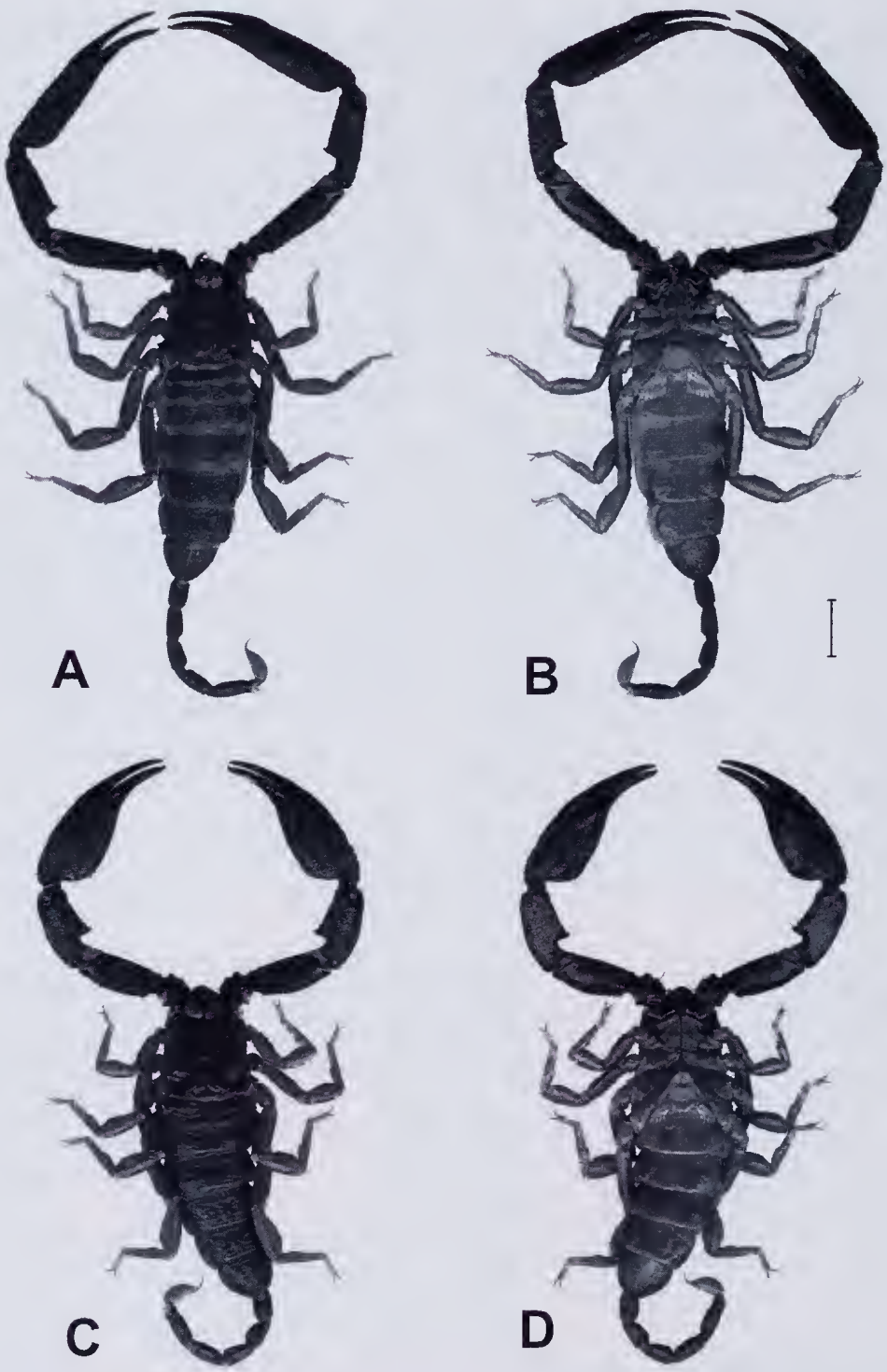


FIG. 2. *Liocheles litodactylus*, male holotype (QMS48320). A, whole animal, dorsal aspect. B, ventral aspect. Female paratype (QMS22452).C, dorsal aspect. D, ventral aspect.

DIAGNOSIS. Dentate margins of the pedipalp chela fingers lacking sculpture in males (Figs 4, 5B) and females.

DESCRIPTION. *Adult Male* (Figs 2A,B; 3A-D; 4; 5B; 6A; 7). *Measurements (holotype).* Carapace, length 6.6, posterior width 7.6; interdistance between anterior lateral eyes 3.4, between posterior lateral eyes 4.5, between median eyes 0.4; diameter of median eyes 0.4. Pedipalp, femur length 10.5, width 2.7; patella length 9.4, width 2.9, chela length 17.9; manus length 10.6, width 3.8, depth 2.4; movable finger length 8.3; fixed finger length 6.0. Metasoma, segment I length 2.4, width 1.7; segment V length 4.4, width 1.2, depth 1.2; vesicle length 4.3, width 1.3, depth 1.4, aculeus length 1.3. Total length 46.5.

Carapace (Fig. 3A). Colouration mostly uniformly tan-brown, with darker brown markings on anterior margins and around median ocular tubercle; posterior and lateral surfaces with faint to distinctive brown reticulate markings; posterior and lateral margins lighter tan with fewer dark markings than on lateral surfaces; median and lateral ocular tubercle blackish brown. Carapace strongly flattened; median ocular tubercle weakly developed, low; sides nearly parallel in the posterior half, convergent in anterior half; frontal concavity or notch moderately developed; anterior lobes rounded; lateral ocular tubercles with 3 ocelli of equal size. Carapace with numerous fine granules and very few nongranular areas; inter-ocular triangle area shagreened; lateral surfaces with both smooth and shagreened patches; anteromedian furrow narrow, suturiform, anteriorly bifurcated; median longitudinal furrow shallow, continuous from the anterior suture furcation, running through ocular tubercle posteriorly into a shallow, smooth and shiny triangular depression; posterolateral furrow shallow, smooth and shiny; mesolateral furrow weekly developed, almost absent.

Mesosoma. Tergite colouration tan-brown with darker brown markings, similar to or slightly lighter than those on carapace; tergite VII slightly darker than other tergites. Tergites I-VI with median carina reduced to a weak non-granular ridge surrounded by a pair of shallow, smooth submedian depressions; lateral carinae absent. Tergite VII with median carina and submedian depressions weakly pronounced, almost absent; lateral and sublateral carinae absent. Surface of tergites predominantly shagreened with scattered granules; possessing a subreticulate formation of low ridges forming numerous irregular shallow dimples; median area of tergites I-III smooth, without granules and minutely pitted; tergites IV-VII with few tiny smooth patches in median area (patches strongly reduced on most posterior tergites); pre-tergites smooth, shiny and minutely pitted. Sternite colouration pale brownish cream anteriorly, becoming progressively darker posteriorly (to pale brown or tan). Sternites III-VI smooth, shiny and minutely pitted, without granulation or carinae. Sternite VII with similar surface texture as on preceding sternites, except for posterolateral region, coarsely textured and slightly shagreened with few small granules; reduced pair of median carinae present in the posterior region; lateral carinae absent. Spiracles of book lungs crescent-shaped.

Metasoma (Fig. 3D). Short and narrow, shagreened, with scattered granules. Colour tan-brown with numerous subreticulate dark brown markings, fewer markings on dorsolateral surfaces. Segments I-IV with longitudinal dorsomedian furrow and without dorsal, dorsolateral and lateral carinae. Segment I: ventrolateral carinae absent, paired ventral carinae reduced to smooth ridges with tuberculate granules in posterior half. Segment II without ventrolateral carinae, indicated only by a row of few scattered granules; paired ventral carinae reduced to ridges with tuberculate granules on posterior half. Segments III-IV without ventrolateral carinae, indicated only by a row of few scattered granules; paired ventral carinae reduced to ridges with few scattered granules along whole length of segment. Segment V without ventrolateral keels; ventromedian carina reduced to a row of few scattered granules.

Telson (Fig. 3D). Vesicle pale yellowish tan; aculeus darker tan due to stronger sclerotisation; vesicle elliptical or ovate; ventrolateral furrows absent; ventromedian ridge absent; lateral surfaces smooth, nongranular and minutely pitted. Macrosetae very sparse basally, becoming more numerous near base of aculeus. Aculeus stout (equal to or shorter than vesicle depth), moderately curved.

Chelicerae (Fig. 3B). Colour pale yellowish tan; manus without markings basally, with fine dark reticulation in distal half merging with large distal brown patch extending onto basal half of fixed finger; fixed finger dark brown in basal two thirds, becoming lighter internally and distally. Typical tooth arrangement of Scorpionidae (see Vachon, 1963); fixed finger with median and basal teeth bifid; movable finger with one subdistal tooth and one basal tooth in external series; distal external tooth smaller than distal

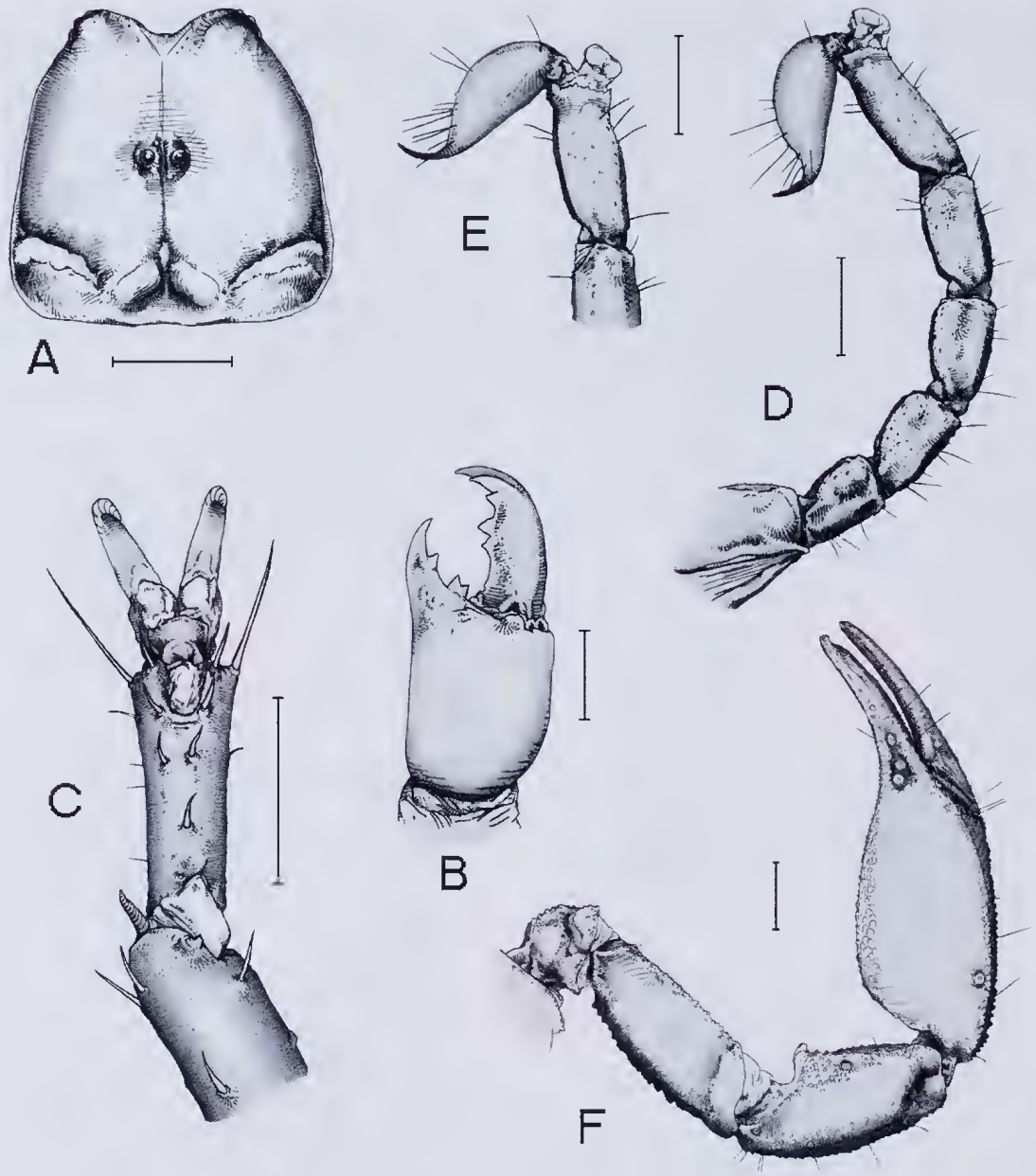


FIG. 3. *Liocheles litodactylus*, male paratype (QMS35475). A, carapace, dorsal aspect. B, right chelicera, dorsal aspect. C, left tarsus IV, ventral aspect. D, metasoma, lateral aspect. Female paratype (QMS35476). E, metasomal segment V and telson, lateral aspect. F, pedipalp, dorsal aspect. Scale lines: A, D-F, 2.5mm; B, C, 1mm.

internal tooth; cheliceral teeth without secondary serrations.

Pedipalp Coxa and Femur (Fig. 4D-F). Pedipalp slender and elongated. Coxa with internoventral margin strongly granular. Dorsal surface of femur predominantly dark tan brown, internal margins distinctly blackish, external and basal margins less intensely blackish, distal margin with only fine black markings; internal surface

entirely blackish; external surface with only ventral margin blackish; ventral surface with internal, external and basal margins blackish. Femur slender, elongate (length equal to or longer than 3 × the width), pentacarinate, with 4 distinct carinae; internodorsal carina developed as a strongly and densely granular ridge, granules coarse; externodorsal carina reduced to a slightly raised row of scattered coarse granules; internoventral carina developed as a weakly granular ridge; externoventral carina developed as a weakly granular ridge with few strongly developed spiniform granules; ventromedian carina reduced to few granules and confined to base of femur. Dorsal surface shagreened, finely and densely granular, distal end smooth, minutely pitted, without granules; internal surface shagreened, sparsely granular; external surface smooth; ventral surface smooth and sparsely granular, distal quarter minutely pitted, without granules. A total of 3 trichobothria present; *d* located externobasally on dorsal surface; *i* located dorsobasally on internal surface; *e* located dorsobasally on external surface.

Pedipalp Patella (Fig. 4D-F). Slender (length less than 2.5 × the width). Colour predominantly dark tan-brown with black markings; dorsal surface with internal and external margins distinctly blackish, distal end blackish red; internal surface completely blackish; external surface with blackish margins; ventral surface with internal and external margins distinctly blackish, distal end light brown, almost yellow. Seven carinae present, 6 of them distinct; internodorsal carina developed as a ridge of coarse granules with few larger spiniform granules; externodorsal carina weakly developed, reduced to a row of scattered coarse granules; internoventral carina developed as a strongly granular ridge (spiniform granules); externoventral carina developed as a strongly granular ridge (coarse granules); externomedian carina developed as a raised darker row of coarse granules. Dorsal surface shagreened and coarsely granular, with smooth and shiny patches, distal end smooth, minutely pitted, without granules; internal surface shagreened and finely granular; external surface shagreened with a few scattered granules; ventral surface smooth and shiny with a sub-reticulate formation of shagreened and low granular ridges, distal end minutely pitted, without granules. Internal protuberance pronounced, trifid (internal, internodorsal and internoventral tubercles fused into a single large spur). A total of 19 trichobothria present; d_1 located basally, external to internodorsal carina; d_2 located in the distal half of patella; d_3 absent; *i* in distal third of patella, located dorsally on internal surface. External (*e*) trichobothrial group discernible and orthobothriotaxic: *eb* group composed of five trichobothria, *esb* group of two trichobothria, *em* group of two trichobothria, *et* group of three trichobothria; *est* very close to *em* group. Ventral (*v*) group orthobothriotaxic, three trichobothria.

Pedipalp Chela Manus (Figs 4A-C; 5B). Colour predominantly dark reddish brown with black markings; dorsal surface with internal and external margins distinctly blackish, distal end blackish; internal surface blackish red, median carina black; external surface dark red with blackish margins; ventral surface with external margins distinctly blackish, distal end dark red, almost black. Chela slender (length more than 4 × the width) with five clear carinae; internodorsal carina continuous with low spiniform granules; subdigital carina absent; externodorsal carina distinct, visible as a strongly granular ridge of coarse granules; digital carina well-developed, granules extending from externodorsal carina onto fixed finger; dorsal secondary carina (dorso-median) much reduced, very weakly indicated by larger granules in basal three quarters of manus; internoventral carina continuous, visible as a row of scattered coarse granules; externoventral carina continuous, crenulate with well developed granules, running parallel to longitudinal axis of chela, distal edge disconnected from external movable finger condyle and directed between external and internal movable finger condyles; ventromedian carina poorly developed, reduced to scattered granules (more numerous basally); internal (internomedian) carina and external (externomedian) carina slightly distinct, visible as raised rows of coarse granules highlighted by a dark line. Dorsal surface smooth and shiny, with numerous coarse granules surrounded by small shagreened areas; internal surface sparsely granular with a denser patch of coarse spiniform granules dorsodistally; external surface shagreened with coarse spiniform granules; ventral surface smooth, with few scattered granules, distal end minutely pitted, without granules. A total of 16 trichobothria present; *Db* trichobothria located basally on external surface; *Dt* located on dorsal surface, in basal third of manus; *Eb* group (3 trichobothria) orthobothriotaxic, located basally on external surface; *Esb* located approximately midway between *Eb* group and *Est*; *Em* absent; *Est* located

submedially; *Et* group composed of five trichobothria, Et_1 located ventrally; *V* group comprising 4 trichobothria, *V3* and *V4* located in the basal third of manus, *V1* and *V2* located in the distal quarter; dorsal trichobothrial salcus undivided, encircling *db*, *dsb* and *dst*; undivided manus salcus encircling Et_{2-4}, and Eb_5 narrowly connected to external finger salcus.

Pedipalp Chela Fingers (Figs 4A-C; 5B). Basally black, becoming gradually lighter (blackish red) distally, tips of fingers tan brown. Dorsal surface with basal half of fingers shagreened and granular, distal half smooth, shiny, with a few punctations; ventral surface predominantly smooth, shiny and minutely pitted. Fingers without distal diastema [A distinct non-granular and non-denticular space between the most distal granule of the denticular row/rows and the terminal tooth of the chela finger. This character occurs in *Heteroscorpion* (Heteroscorpionidae), previously considered a liochelid (ischnurid) (Lourenço, 1985, 1989).]. Tips of fingers with pronounced distal hook; denticular margins straight. Fixed finger without basal concavity or any lobe. Movable finger without sculpturing on denticular margin; base of external surface with a group of 3 to 4 (usually 3) whitish spots with glandular appearence. A total of 10 trichobothria present; *db* and *dsb* in very basal portion of finger, on dorsal surface; *dst* in basal half of finger; *dt* located submedially on finger, on internodorsal surface of finger; *eb* in very distal portion of manus, near base of fixed finger, located basally to *db*; *esb* in far distal portion of manus, near base of fixed finger, opposite *dst*; *est* in basal portion of finger, between *dst* and *dsb*; *et* submedially on finger, distal to *dst*, opposite *dt*; *it* and *ib* located in distal portion of manus, proximal to base of fixed finger, on internal side of manus; salcus of external finger divided into 2 parts between *eb* and *esb*.

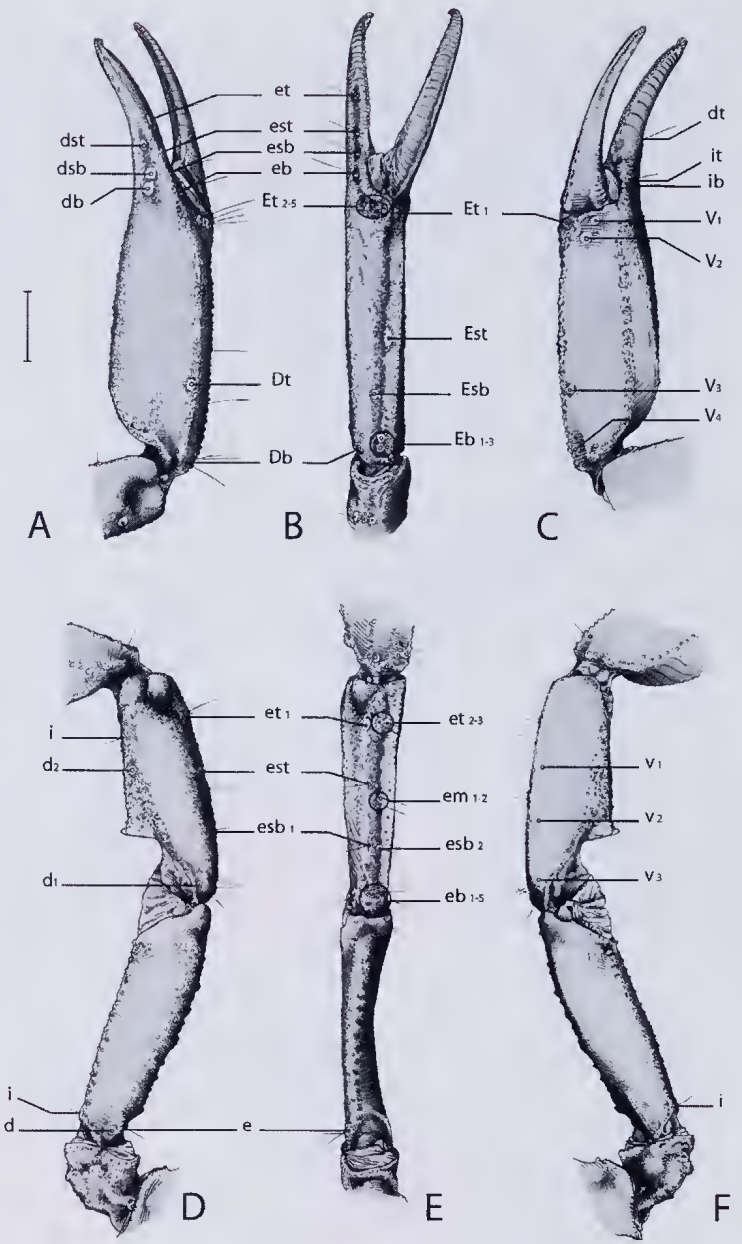


FIG. 4. *Liocheles litodactylus*, male paratype (QMS35475), pedipalp with trichobothrial pattern, chela. A, dorsal aspect. B, external aspect. C, ventral aspect. Femur and patella. D, dorsal aspect. E, external aspect. F, ventral aspect. Scale line 2.5mm

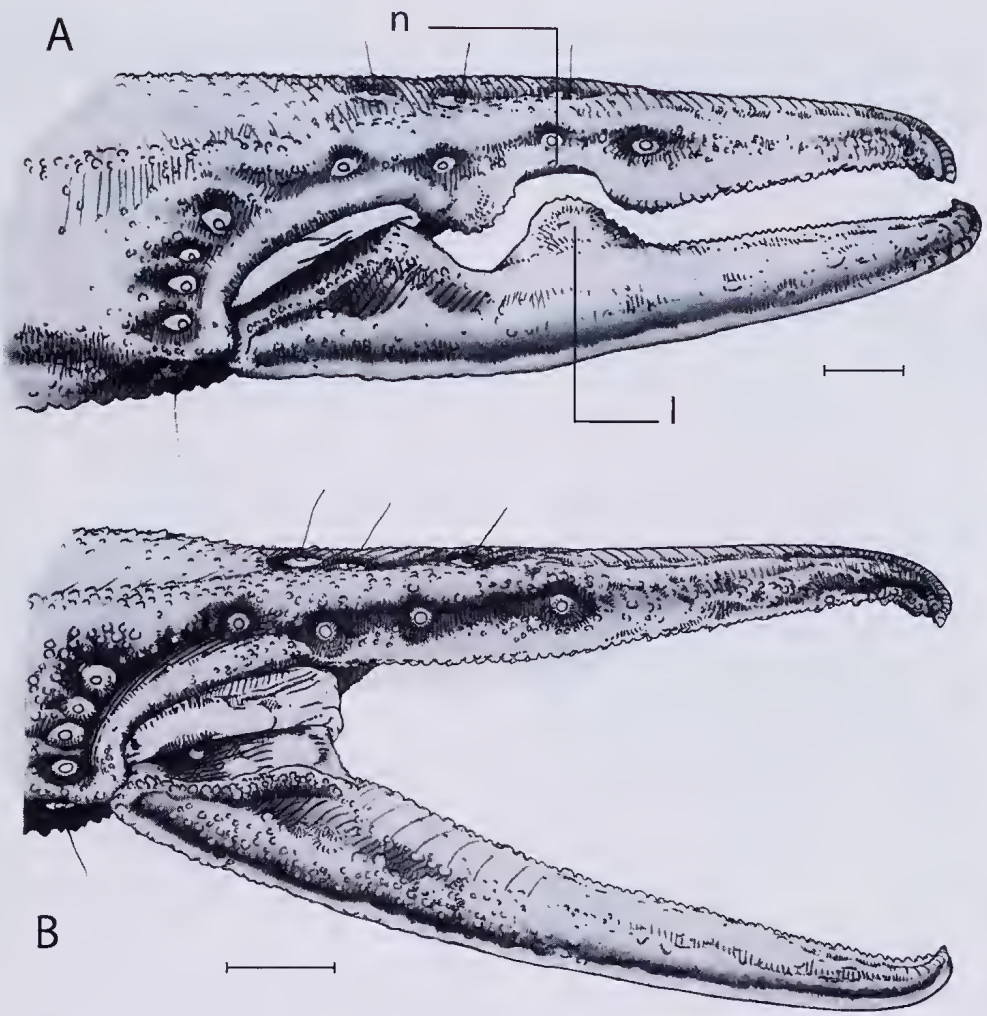


FIG. 5. External aspect of pedipalp chelae fingers. A, male *Liocheles* sp. from Hinchinbrook Island, North Queensland (QMS23260). B, male *L. litodactylus* (QMS35475). Note the presence of a lobe (l) on the movable finger and of a corresponding notch (n) on the fixed finger in A, and the lack of these structures in B. Scale lines 1mm.

Coxosternal Sclerites. Pale yellowish tan to orange; smooth and minutely pitted. Coxapohysis I with anterior margin slightly granular, expanded but not sub-triangular in shape. Sternum of type 2 (Soleglad & Fet, 2003), subpentagonal, smooth and minutely pitted; median furrow very shallow, present only in posterior half; posterior pit absent.

Legs. Pale yellowish tan; dorsal surfaces of coxa, trochanter, femur and patella with tan brown subreticulate markings; dorsal surfaces of tibia and basitarsus with distal ends tan-brown; internal margin of femur darker brown. Dorsal surfaces of trochanter, femur and patella shagreened and sparsely granular; ventral surface smooth, shiny and minutely pitted. Tarsi without ventromedian row of setae and with 2 rows of ventral macrosetae, prolateral row with 3 macrosetae, retrolateral row with 4 macrosetae, one or 2 spinules at base (usually a single spinule present); setae coarse and acuminate; tarsal claws of equal length.

Pectines and Genital Operculum (Fig. 6A). Colour pale yellowish tan, without dark markings; genital operculum composed of 2 triangular plates; genital papillae short, not or

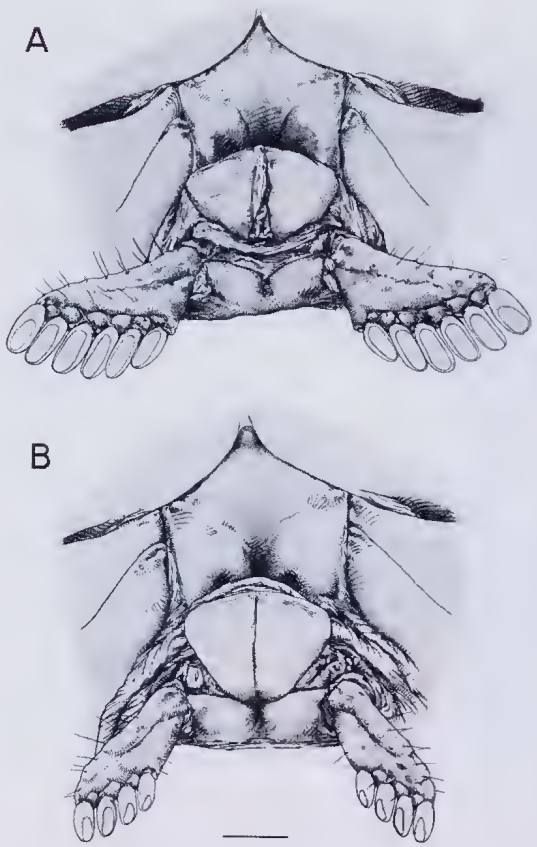


FIG. 6. *Liocheles litodactylus*, pectines and genital opercula. A, male paratype (QMS35474). B, female paratype (QMS35476). Scale line 1mm.

only slightly protruding from beneath operculum: pectines with 6/6 teeth.

Hemispermatophore (Fig. 7). Lamelliform with complex capsule; distal lamellum stout, distally rounded, with a small hook, flagellum length approximately equal in length to that of a capsule region; distal crest absent. Single lamellar hook (h) located below distal lamella base, visible as a short tuberculate protrusion. Distal transverse ridge (Tr) costate, distally strongly curved towards posterior margin, continuous from posterior to anterior margins, not merging with lamellar hook, reaching anterior margin of distal lamella above its hook. Capsule orientation: distal lamella seen nearly edge on in capsular view [the view in which greatest detail of the capsule lamellae and lobes can be determined] (Fig. 7B). Capsule lamella (La) broad and terminally rounded (Fig. 7B,D), forming an acute angle to longitudinal axis of capsule; ventral margin straight (Fig. 7B,D). Distal lobe (Ld) broadly subtriangular; basal margin straight (Fig. 7B,E). Basal lobe (Lb) broad, its internal margins round (Fig. 7B,C). Posterior lamella (Pl) costate and directed distally (Fig. 7B,E).

Adult female (Figs 2C,D; 3E,F; 6B). Measurements (QM-S22452). Carapace; length 7.4, posterior width 8.5; interdistance between anterior lateral eyes 3.9, between posterior lateral eyes 5.0, between median eyes 0.4; diameter of median eyes 0.3. Pedipalp, femur length 8.6, width 3.1; patella length 8.0, width 3.3; chela length 16.6; manus length 9.5, width 5.4, depth 2.9; movable finger length 8.4; fixed finger length 6.2. Metasoma, segment I length 2.3, width 1.8; segment V length 4.3, width 1.3, depth 1.4; vesicle length 4.6, width 1.4, depth 1.4; aculeus length 1.5. Total length 53.0.

Same characters as in males except as follows. Carapace surface almost entirely smooth and minutely pitted, with very few shagreened and granular patches. Tergites predominantly smooth, shiny and minutely pitted, with surface like a subreticulate formation of low ridges forming numerous irregular shallow dimples. Metasoma (Fig. 3E) smooth and minutely pitted, with very few shagreened areas and granules; ventral surface of segments III-V predominantly shagreened. Pedipalp stout and bulky (Fig. 3F); femur length less than 2.5× the width; patella length less than 2× the width; chela length less than 3.5× the width. Pedipalp chela manus less strongly carinated than in males, dorsal secondary carina not discernible. Both halves of genital operculum completely fused, triangular, with posterior extremity truncated, with a shallow median longitudinal suture and a slightly pronounced posterior notch; pectines with 4/4 teeth (Fig. 6B).

DISTRIBUTION. Thornton Uplands, Far North Queensland (Fig. 8).

DISCUSSION

TAXONOMIC CHARACTERS. *Pedipalpal morphosculpture.* The presence of a lobe on the movable finger of the pedipalp chela and of a corresponding notch on the fixed finger is usually indicative of sexual maturity in males and females of the liochelids *Chiromachus*, *Iomachus*, *Hadogenes*, *Opisthacanthus* (subgenus *Nepabellus*) and *Paleochelochtonus* (Prendini, 2000). Subadults lack this feature, which occurs only in the final instar. However, within *Hadogenes*, adult females of some species of the

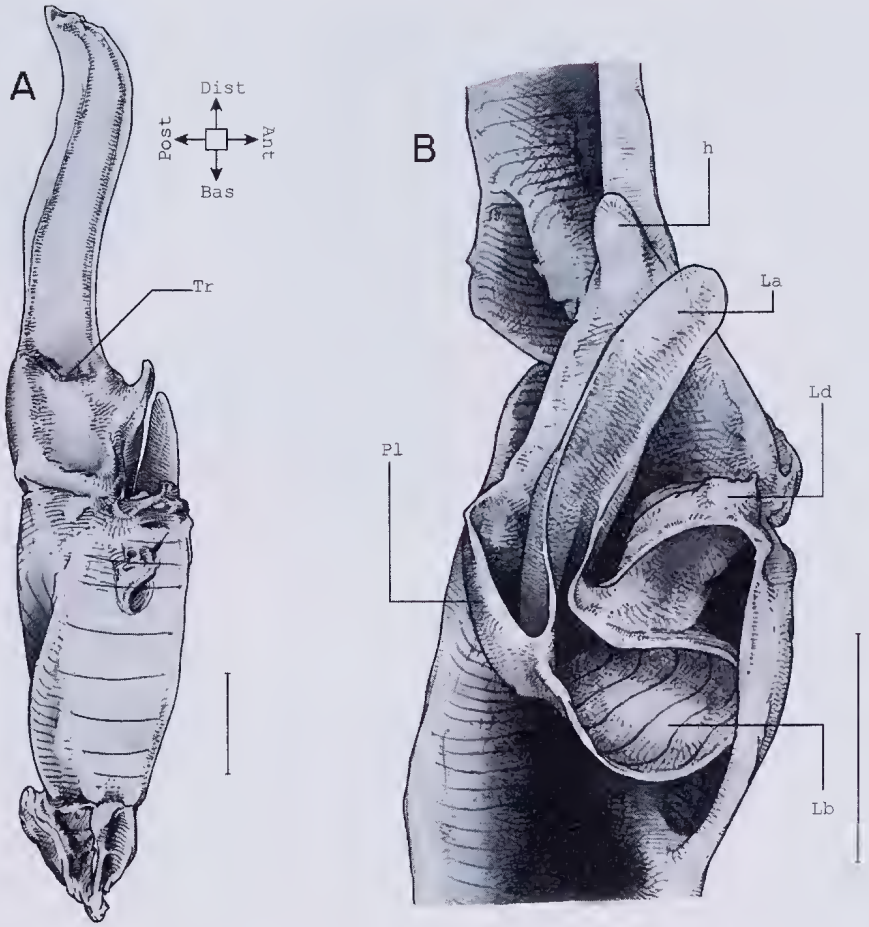


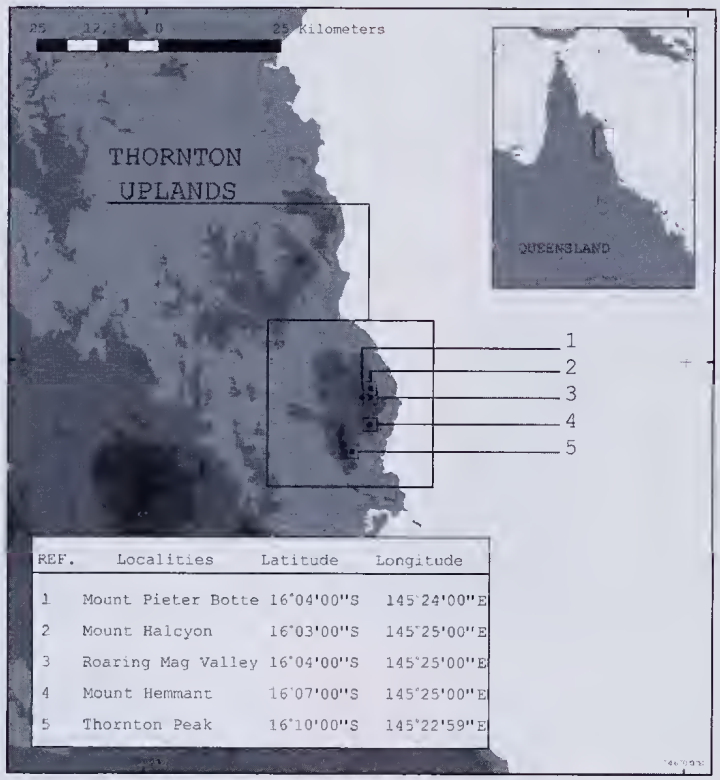
FIG. 7. *Liocheles litodactylus*, male paratype (QMS35475), hemispermatophore. A, hemispermatophore with arrows indicating post-extrusion orientation of the hemispermatophore, Ant (anterior), Bas (basal), Dist (distal), Post (posterior), Tr (transversal ridge). B, detail of the capsular region, internal aspect, h (hook), La (lamella), Lb (basal lobe), Ld (distal lobe), Pl (posterior lobe). Scale lines (A, B) 1mm.

H. tityrus (Simon) species complex, as well as males and females of *H. zumpti* Newlands & Cantrell, are without any lobe and notch (Newlands & Prendini, 1997). In all previously described species of *Cheloctonus* and *Liocheles* only mature males possess this character, whereas females do not. *Liocheles litodactylus* is the only known representative of the genus in which males possess chela fingers without such a sculpturing on their denticular margins. Sexually mature males of *L. litodactylus* were initially assessed by the presence of fully developed paraxial organs and hemispermatophores (Fig. 7). Despite the highly unusual pedipalp chela of males, this species is clearly a representative of *Liocheles*, as evidence from other morphological characters noted above in the diagnoses of the corresponding higher taxa. Prendini (2000: fig. 2) demonstrated that *Liocheles* represents the most derived liochelid and that its monophyly is well supported in contrast to other Liochelidae. The other liochelid genera were placed more basally on all most parsimonious cladograms that he found (Prendini, 2000: figs 2,5,6). Strong evidence of the monophyly of *Liocheles* and of its terminal position in the Liochelidae indicates that the unique pedipalpal morphology of the *L. litodactylus* male represents an autapomorphic loss of the sculpturing found in all other congeneric species.

An additional feature not reported in other species of *Liocheles* is the presence of an irregular cluster

of pale spots (2-4) of glandular appearance, located in the basal half of the external face of the movable finger. Nothing is known about the function of this feature and it is apparently unique to this species.

Sexual Dimorphism. Like in all liochelids, the genital operculum of *L. litodactylus* males consists of two separate sclerites which cover a pair of genital papillae, whereas females possess an undivided genital operculum. Secondary sexual characters in which adult males differ from adult females are: more slender pedipalps; stronger granulation of carapace, tergites and metasoma; greater number of pectinal teeth.



REF.	Localities	Latitude	Longitude
1	Mount Pieter Botte	16°04'00"S	145°24'00"E
2	Mount Halcyon	16°03'00"S	145°25'00"E
3	Roaring Mag Valley	16°04'00"S	145°25'00"E
4	Mount Hemmant	16°07'00"S	145°25'00"E
5	Thornton Peak	16°10'00"S	145°22'59"E

FIG. 8. Map showing the localities of *L. litodactylus* in the Australian Wet Tropics (with a list of localities and their geographic coordinates). Hypsography of the area is represented by graduated grey scale, dark grey representing the highest altitudes. The inset shows the location of the area in Queensland.

BIOGEOGRAPHY AND EVOLUTION

Koch (1977) recognised only three Australian species of *Liocheles* and concluded that *L. waigiensis*, which is widely distributed along the Australian east coast, was a highly variable species. Monod (2000) carried out a revision of all *Liocheles* spp. and pointed out that species richness is much higher than previously reported, especially within the Australo-Papuan *L. waigiensis* complex. Five valid species are known in this group (i.e., *L. extensus*, *L. karschi*, *L. litodactylus*, *L. penta* and *L. waigeinsis*), but an ongoing taxonomic study by the senior author indicates approximately 25 distinct forms. Eleven valid species and subspecies of *Liocheles* are recognised worldwide: *L. australasiae australasiae*, *L. australasiae brevidigitatus* (Werner, 1936), *L. australasiae longimanus* (Werner, 1939), *L. davidovi* (Fage, 1933), *L. extensus*, *L. karschii*, *L. litodactylus*, *L. nigripes* (Pocock, 1897), *L. penta*, *L. polisorum* and *L. waigiensis*. Four species, *L. extensus*, *L. karschii*, *L. litodactylus* and *L. waigiensis* are confined to the Australo-Papuan region. With the description of additional new species (mostly from the Australo-Papuan region) imminent, this region seems to contain the greatest diversity. A brief overview follows of the climatological events that most likely shaped the current distribution of habitats in the region and led to the speciation of *L. litodactylus*.

The rainforests discontinuously distributed along the NE coast of Queensland from Cooktown to north of Townsville form a region known as the Wet Tropics. This region consists of a series of isolated mountains and tablelands rising up to 1,600m in altitude, which are surrounded by lowland forests at sea level. The faunal and floral composition of the upland regions (altitude above 300m) is notably different from the lowland mesophyll forest. Nix (1991) described the upland rainforests of the Wet Tropics as a mesotherm archipelago in a sea of tropical lowlands. Fourteen upland rainforest subunits have been recognised (McDonald, 1992; Moritz et al., 2001; Williams, 1997; Williams & Pearson, 1997; Williams et al., 1996; Winter et al., 1984; Yeates et al., 2002).

The rainforests of the Wet Tropics are considered to be remnants of previously widespread

homogenous Tertiary vegetation (Truswell, 1993). Progressive continental drying since the Miocene induced the transformation of the Australian landscape, previously dominated by rainforest, to one dominated by grasslands and woodlands, in which rainforest became very reduced in extent (Kershaw et al., 1994). By the beginning of the Pleistocene the moist area has greatly declined, with rainforest elements segregated along the eastern coast in a similar pattern to that seen today (Adam, 1992). Smaller scale expansions and contractions of rainforest have coincided with recent Quaternary glaciation events (Heatwole, 1987; Kershaw, 1994). During these glacial maxima rainforests within the Wet tropics were replaced by open sclerophyll forests. During the last glacial maximum (between 13000 and 8000 years BP) rainforests contracted to a series of small, fragmented refugia on the highest mountain tops and plateaus, separated by gaps of dryer sclerophyll vegetation (Adam, 1992; Hopkins et al., 1993; Webb & Tracey, 1981).

The occurence of the *Liocheles* in Australian was thought to be the result of invasion, presumably over land bridges, of ancestral species from Southeast Asia (Koch, 1977, 1981). The most likely route is via a broad land bridge between present day Cape York Peninsula that connected North Queensland and New Guinea during glaciation maxima. After invading Australia from the north, *Liocheles* would have spread southwards in eastern Queensland. However, an ongoing phylogenetic and biogeographic study of *Liocheles* and related genera by the senior author emphasises that the Australian distribution range of *Liocheles* is not a result of dispersal from Asia via New Guinea. Several new findings contradict Koch's view and support the theory that *Liocheles* probably originates from eastern Gondwana (today's Australo-Papuan area) and invaded Southeast Asia after the breakup and dispersion of Gondwana. *Liocheles* was present in Australia well before the glaciation events of the Pleistocene and then was probably widespread in rainforests all over the continent. The repeated climate changes and rainforest contractions that occurred during the Quaternary most likely stranded a population of *Liocheles* on the Thornton Uplands. In which, in isolation from surrounding rainforests (Fig. 7) and gene-flow from conspecifics in neighbouring rainforests, the population evolved allopatrically into the form that is here described as *L. litodactylus*. Isolation of other populations of *Liocheles* on similar 'rainforest islands' in NE Queensland provides extensive potential for numerous allopatric speciation events. By causing isolation and subsequent radiative evolution of populations of taxa with low powers of dispersal on high altitude refugias (Brühl, 1997), rainforest contractions in the Wet Tropics have enhanced a high degree of 'local endemism' in the region. Consequently several other unrelated taxa show congruent distributions and presumably result from similar vicariance events (Joseph et al., 1995; Schneider et al., 1998; Schneider & Moritz, 1998; Stuart-Fox et al., 2001; Williams, 1997; Williams et al., 1996).

Liocheles litodactylus occurs in highland rainforests of Far North Queensland. We believe that it is locally endemic to the Thornton Uplands, a small mountain massif north of Mossman, for the following reasons:

1) All specimens examined were collected in high altitude rainforests above 700 m. This vegetation type is very limited in extent within the Wet Tropics, being restricted to topslopes of granitic highlands (Tracey & Webb, 1975).

2) The Thornton uplands was recognised as a biogeographic subregion of the Wet Tropics by Winter et al. (1984) and in subsequent publications by other authors (Williams et al., 1996; Yeates et al., 2002).

3) During the past 20 years, the Queensland Museum has conducted numerous surveys of the terrestrial invertebrate fauna of the Wet Tropics (Monteith, 1985, 1995; Monteith & Davies, 1991). Approximately 350 sites were visited and a conscious effort was made to sample every mountain massif more than once over many years. Therefore, the restricted occurrence of this species most probably reflects the extent of the distribution of this species, and is not an artefact of insufficient sampling.

Harvey (2002) defined a short range endemic as a species that is naturally confined to an area of less than 10,000km^2. All available evidence indicates that *L. litodactylus* is a short range endemic species that is confined to the Thornton Uplands (an area less than 1,000km^2). *Liocheles litodactylus* is the only Australian scorpion that can be defined as a short range endemic. Ongoing studies on *Liocheles*, and on Buthidae and Urodacidae by the junior author indicate that the Australian scorpion fauna is much richer than currently recognised and that more short range endemic species exist, particularly in northern Australia.

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LITERATURE CITED

ADAM, P. 1992. Australian rainforests. (Oxford University Press: Melbourne).

BRÜHL, C.A. 1997. Flightless insects; a test case for historical relationships of African mountains. Journal of Biogeography 24: 233-250.

FABRICIUS, J.C. 1775. Systema entomologiae sistens insectorum classes, ordines, genera, species, adjectis synonymis, locis, descriptionibus, observationibus. (Flensburgi et Lipsiae: Leipzig).

FAGE, L. 1933. Les scorpions de l'Indochine française, leur affinités, leur distribution géographique. Annales de la Société Entomologique de France 102: 25-34.

FET, V. & BECHLY, G. 2001. Liochelidae, fam. nov. (Scorpiones): proposed introduction as a substitute name for Ischnurinae Simon, 1879, as an alternative to the suggested emendment of Ischnurinae Fraser, 1957 (Insecta, Odonata) to Ischnurainae in order to remove homonymy. Bulletin of Zoological Nomenclature 58: 280-281.

FRANCKE, O.F. 1974. Nota sobre los genero *Opisthacanthus* Peters y *Nepabellus* nom. nov. (Scorpionida, Scorpionidae) e informe sobre el hallagzo de *O. lepturus* en la Isla de Coco, Costa Rica. Brenesia 4: 31-35.

FRANCKE, O.F. & LOURENÇO, W.R. 1991. Scorpions (Arachnida) from Rennell Island. The Natural History of Rennell Island, British Solomon Islands 8: 199-204.

GERVAIS, P.M. 1843. Les principaux résultats d 'un travail sur les famille des Scorpions. Société Philomatique de Paris. Extraits des Procès-Verbaux des Séances 5: 129-131.

HARVEY, M.S. 2002. Short-range endemism in the Australian fauna: some examples from non-marine environments. Invertebrate Systematics 16: 555-570.

HEATWOLE, H. 1987. Major components and distributions of the terrestrial fauna. Pp. 101-135. In Dyne, G.R. & Walton, D.W. (eds) Fauna of Australia 1a. (Australian Government Printing Service: Canberra).

HJELLE, J.T. 1990. Anatomy and Morphology. Pp. 9-63. In Polis, G.A. (ed.) The biology of scorpions. (Stanford University Press: Stanford).

HOPKINS, M.S., ASH, J.E., GRAHAM, A.W., HEAD, J. & HEWETT, R.K. 1993. Charcoal evidence of the spatial extent of the Eucalyptus woodland expansions and rain forest contractions in North Queensland during the late Pleistocene. Journal of Biogeography 20: 357-372.

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE 2003. Opinion 2037 (Cases 3120 and 3120a). Liochelidae Fet & Bechly, 2001 (1879) (Scorpiones): adopted a s a valid substitute name for Ischnuridae Simon, 1879 in order to remove homonymy with Ischnurinae Fraser, 1957 (Insecta, Odonata). Bulletin of Zoological Nomenclature 60: 159-161.

JACOBSON, E.R. 1909. Die niewe fauna van Krakatau. Jaarverslag van den Topographischen Dienst in Nederlandsch-Indië 4: 192-206.

JOSEPH, L., MORITZ, C. & HUGALL, A. 1995. Molecular support for vicariance as a source of diversity in rainforest. Proceedings of the Royal Society of London (B) 260: 177-182.

KARSCH, F. 1880. Arachnologische Blätter. X. Scorpionologische Fragmente. Zeitschrift für die Gesellschaft der Naturwissenschaften 53: 404-409.

KERSHAW, A.P. 1986. The last two glacial-interglacial cycles from northeastern Australia: implications for climatic change and Aboriginal burning. Nature 322: 47-49.

1994. Pleistocene vegetation of the humid tropics of northeastern Queensland, Australia. Palaeogeography, Palaeoclimatology, Palaeoecology 109: 399-412.

KERSHAW, A.P., MARTIN, H.A. & McEWEN MASON, J.C.R. 1994. The Neogene: a period of transition. Pp. 299-327. In Hill, R.S. (ed.) History of the Australian vegetation: Cretaceous to Recent. (Cambridge University Press).

KEYSERLING, E. 1885. Die Arachniden Australiens. Pp. 1-48. In Koch, L. & Keyserling, E. (eds) Die Arachniden Australiens nach der Natur beschrieben und abgebildet 32. (Bauer & Raspe: Nürnberg).

KOCH, C.L. 1837. Scorpiones. Pp. 36-39. In Übersicht des Arachnidensystems 1. (C.H. Zeh'sche Buchhandlung: Nürnberg).

1867. Beschreibungen neuer Arachniden und Myriapoden. Verhandlungen der Kaiser-Königlichen Zoologischen-Botanischen Gesellschaft in Wien 17: 173-250.

KOCH, L.E. 1977. The taxonomy, geographic distribution and evolutionary radiation of Australo-Papuan scorpions. Records of the Western Australian Museum 5: 83-367.

1981. The scorpions of Australia: aspects of their ecology and zoogeography. Pp. 875-884. In Keast, A. (ed.) Ecological biogeography of Australia 2. (Junk: The Hague).

KOPSTEIN, F. 1935. Skorpione von Krakatau und den benachbarten Inseln. Treubia 15: 209-210.

LAMORAL, B.H. 1979. The Scorpions of Namibia (Arachnida: Scorpionida). Annals of the Natal Museum 23: 497-784.

LATREILLE, P.A. 1802. Histoire naturelle, générale et particulière des Crustacés et des Insectes. 3. (F. Dufart: Paris).

LOCKET, N.A. 1995. A new Ischnurid scorpion from the Northern Teritory, Australia. Records of the Western Australian Museum 52: 191-198.

1997. *Liocheles extensa*, a replacement name for *Liocheles longimanus* Locket, 1995 (Scorpiones: Ischuridae). Records of the Western Australian Museum 18: 331.

LOURENÇO, W.R. 1985. Essai d'interprétation de la distribution du genre *Opistacanthus* (Arachnida, Scorpiones, Ischnuridae) dans les régions néotropicale et afrotropicale. Étude taxinomique, biogéographique évolutive et écologique. Unpubl. PhD thesis, University "Pierre et Marie Curie", Paris.

1989. Rétablissement de la famille des Ischnuridae, distinctes des Scorpionidae Pocock, 1893, à partir de la sous-famille des Ischnurinae Pocock, 1893. Revue Arachnologique 8: 159-177.

McDONALD, K.R. 1992. Distribution patterns and conservation status of north Queensland rainforest frogs. Conservation Technical Report 1. (Queensland Department of Environment and Heritage: Brisbane).

MONOD, L. 2000. Révision systématique du genre *Liocheles* (Ischnuridae, Scorpiones). Unpubl. MSc thesis, University of Geneva.

MONTEITH, G.B. 1985. Altitudinal transect studies at Cape Tribulation, north Queensland VII. Coleoptera and Hemiptera (Insecta). Queensland Naturalist 26: 70-80.

1995. Distribution and altitudinal zonation of low vagility insects of the Queensland Wet Tropics. Report to the Wet Tropics Management Authority. Part 4. (Queensland Museum: Brisbane).

MONTEITH, G.B. & DAVIES, V.T. 1991. Preliminary account of a survey of arthropods (insects and spiders) along an altitudinal rainforest transect in tropical Queensland. Pp. 345-362. In Werren, G. & Kershaw, A.P. (eds) The rainforest legacy: Australian National Rainforest Study 2. (Australian Government Publication Service: Canberra).

MORITZ, C., RICHARDSON, K.S., FERRIER, S., MONTEITH, G.B., STANASIC, J., WILLIAMS, S.E. & WHIFFIN, T. 2001. Biogeographic concordance and efficiency of taxon indicators for establishing conservation priority in a tropical rainforest biota. Proceedings of the Royal Society of London (B) 268: 1875-1881.

NENILIN, A.B. & FET, V. 1992. Zoogeographical analysis of the world scorpion fauna (Arachnida: Scorpiones). Arthropoda Selecta 1: 3-31.

NEWLANDS, G. 1973. Zoogeographical factors involved in the trans-Atlantic dispersal pattern of the genus *Opisthacanthus* Peters (Arachnida : Scorpionidae). Annals of the Transvaal Museum 28: 91-98.

NEWLANDS, G. & CANTRELL, A.C. 1985. A re-appraisal of the rock scorpions (Scorpionidae: *Hadogenes*). Koedoe: 35-46.

NEWLANDS, G. & PRENDINI, L. 1997. Redescription of *Hadogenes zumpti* Newlands and Cantrell 1985: An unusual rock scorpion (Scorpiones, Ischnuridae) from the Richtersveld, South Africa. South African Journal of Zoology 32: 76-81.

NIX, H.A. 1991. Biogeography: patterns and processes. Pp. 1-39. In Nix, H.A. & Switzer, M.A. (eds) Rainforest animals: Atlas of vertebrates endemic to Australia's Wet Tropics. (Australian National Parks and Wildlife Service: Canberra).

PETERS, M.B. 1861. Über eine neue Eintheilung der Scorpione und über die von ihm in Mosambique gesammelten Arten von Scorpionen, aus welchem hier ein Auszug mit getheilt wird. Monatsberichte der Königlichen Preussischen Akademie der Wissenschaften zu Berlin 1861: 507-516.

POCOCK, R.I. 1897. Description of some new species of scorpions from India. Journal of the Bombay Natural History Society 11: 102-117.

1902. A contribution to the systematics of scorpions. I. Some corrections in nomenclature. II. Notes on some species of *Parabuthus* contained in the British Museum. III. Descriptions of some new and old species. Annals and Magazine of Natural History (7)10: 364-380.

PRENDINI, L. 2000. Phylogeny and classification of the superfamily Scorpionoidea Latreille 1802 (Chelicerata, Scorpiones): An exemplar approach. Cladistics 16: 1-78.

2001. Two new species of *Hadogenes* (Scorpiones, Ischnuridae) from South Africa, with a redescription of *Hadogenes bicolor* and a discussion on the phylogenetic position of *Hadogenes*. Journal of Arachnology 29: 146-172.

SCHNEIDER, C., CUNNINGHAM, M. & MORITZ, C. 1998. Comparative phylogeography and the history of endemic vertebrates in the Wet Tropics rainforests of Australia. Molecular Ecology 7: 487-498.

SCHNEIDER, C. & MORITZ, C. 1998. Rainforest refugia and evolution in Australia's Wet Tropics. Proceedings of the Royal Society of London (B) 266: 191-196.

SEYMOUR, J., VOLSCHENK, E. & SCOTT, B. 1995. Record of the scorpion *Liocheles karschii* (Keyserling, 1855) from north east Queensland (Scorpionida: Ischnuridae). Memoirs of the Queensland Museum 38: 532.

SIMON, 1879. 3^{e} Ordre. Scorpiones. Pp. 79-115. In Les Arachnides de France. VII. Contenant les Ordres des Chernetes, Scorpiones et Opilions. (Roret: Paris).

SIMON, E. 1888. Arachnides recueillis dans le sud de l'Afrique par M. le docteur Hans Schinz. Annales de la Société Entomologique de France (6)7: 369-384.

SISSOM, W.D. 1990. Systematics, biogeography, and paleontology. Pp. 64-160. In Polis, G.A. (ed.) The

biology of scorpions. (Stanford University Press: Stanford).

SOLEGLAD, M.E & FET, V. 2003. The scorpion sternum: structure and phylogeny (Scorpiones: Orthosterni). Euscorpius, Occasional Publications in Scorpiology 5: 1-34.

STAHNKE, H.L. 1970. Scorpion nomenclature and mensuration. Entomological News 81: 297-316.

STUART-FOX, D.M., SCHNEIDER, C.J., MORITZ, C. & COUPER, P.J. 2001. Comparative phylogeography of three rainforest-restricted lizards from mid-east Queensland. Australian Journal of Zoology 49: 119-127.

SUNDEVALL, C.J. 1833. Conspectus Arachnidum. (C.F. Berling: Londini Gothorum).

THORELL, T. 1876 (1877). On the classification of scorpions. Annals and Magazine of Natural History (4) 17: 1-15.

TRACEY, J.G. & WEBB, L.J. 1975. The vegetation of the humid tropical region of north Queensland (15 maps and key). (CSIRO: Indooroopilly).

TRUSWELL, E. 1993. Vegetation changes in the Australian Tertiary in response to climatic and phytogeographic forcing factors. Australian Systematic Botany 6: 533-557.

VACHON, M. 1963. De l'utilité, en systématique, d'une nomenclature des dents des chélicères chez les Scorpions. Bulletin du Muséum National d'Histoire Naturelle, Paris (2)35: 161-166.

1974. Étude des caractères utilisés pour classer des familles et les genres de Scorpions (Arachnides). 1. La trichobothriotaxie en Arachnologie. Sigles trichobothriaux et types de trichobothriotaxie chez les Scorpions. Bulletin du Muséum National d'Histoire Naturelle, Paris (3)140: 857-958.

VACHON, M. & ABE, T. 1988. Colonization of the Krakatau islands (Indonesia) by scorpions. Acta Arachnologica 37: 23-32.

VOLSCHENK, E.S., LOCKET, N.A. & HARVEY, M.S. 2001. First record of a troglobitic ischnurid scorpion from Australasia (Scorpiones: Ischnuridae). Pp. 161-170. In Fet, V. & Selden, P.A. (eds) Scorpions 2001: In memoriam Gary A. Polis. (British Arachnological Society: Burhmam Beeches Bucks).

WEBB, L. & TRACEY, J. 1981. Australian rainforests; pattern and change. Pp. 607-694. In Keast, J.A. (ed.) Ecological Biogeography of Australia. (W. Junk: The Hague).

WERNER, F. 1936. Neu-Eingänge von Skorpionen im Zoologischen Museum in Hamburg. Festschrift zum 60. Geburtstage von Professor Dr Embrik Strand 2: 171-193.

1939. Ueber einige Skorpione aus dem Museum Alexander Koenig. Festschrift zum 60. Geburtstag von Professor Embrik Strand 5: 361-362.

WILLIAMS, S.E. 1997. Patterns of mammalian species richness in the Australian tropical forests: are extinctions during historical contractions of the rainforests the primary determinants of current regional patterns in biodiversity? Wildlife Research 24: 513-530.

WILLIAMS, S.E. & PEARSON, R.G. 1997. Historical rainforest contractions, localized extinctions and patterns of vertebrate endemism in the rainforests of Australia's Wet Tropics. Proceedings of the Royal Society of London (B) 264: 709-716.

WILLIAMS, S.E., PEARSON, R.G. & WALSH, P.J. 1996. Distribution and biodiversity of the terrestrial vertebrates of Australia's Wet Tropics: a review of current knowledge. Pacific Conservation Biology 2: 327-362.

WINTER, J.W., BELL, F.C., PAHL, L.I. & ATHERTON, R.G. 1984. The specific habitats of selected northeastern Australian rainforest mammals. (Report to the World Wild Fund for Nature: Sydney).

YEATES, D.K., BOUCHARD, P. & MONTEITH, G.B. 2002. Patterns and levels of endemism in the Australian Wet Tropics rainforest: evidence from flightless insects. Invertebrate Systematics 16: 605-619.

OCCURRENCE OF THE WALLUM FROGLET (*CRINIA TINNULA*) AT LITTABELLA NATIONAL PARK, SOUTHEASTERN QUEENSLAND

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Meyer, E.A., Hines, H.B., Clarke, J.M., Hodgon, J. & Gynther, I. 2004 06 30: Occurrence of the wallum froglet (*Crinia tinnula*) at Littabella national park, southeastern Queensland. *Memoirs of the Queensland Museum* 49(2): 691-692. Brisbane. ISSN 0079-8835.

In June 2002, surveys for the vulnerable Wallum Froglet (*Crinia tinnula*) were undertaken at Littabella, Eurimbula and Deepwater National Parks, south-east Queensland. The presence of *C. tinnula* was confirmed at two sites within Littabella NP. Despite the presence of suitable habitat, *C. tinnula* was not recorded at either Eurimbula or Deepwater National Parks. Based on these results the northern limit of *C. tinnula*'s distribution would appear to be Littabella National Park. ❑ *Crinia tinnula, froglett, occurence.*

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The vulnerable Wallum Froglet (*Crinia tinnula*) occurs from Kurnell, NSW (34°02'S, 151°13'E) to Fraser Island, Qld (Hines et al., 1999). On Fraser I., *C. tinnula* has been recorded as far north as Lake Wonjeel (24°53'S, 153°14'E) (Hines et al., 1999; Queensland Museum records). On the mainland, *C. tinnula* has not been confirmed north of Woodgate National Park (25°07'S, 152°34'E) (Hines et al., 1999).

During surveys in May 1997, Clarke et al. (1998) recorded *C. tinnula* at Littabella National Park (NP) (24°35'S, 152°03'E), north of Fraser I. and 75km north of Woodgate NP. Doubt, however, was cast on these records as the identification of voucher specimens could not be confirmed (Hines et al., 1999). (All but one of these, a single specimen lodged with the Queensland Museum [registration number QMJ63347], appear to have gone missing). Adding to doubt over these records is the likely occurrence of *Crinia parinsignifera* and/or *C. deserticola* (species easily confused with *C. tinnula*) at Littabella NP. Follow-up surveys were therefore undertaken to determine whether *C. tinnula* does indeed occur as far north as Littabella NP.

Following heavy rain in early June 2002 (>100mm in 7 days), EM, HH and JH surveyed sites at Littabella NP for *C. tinnula*. In addition, EM and HH undertook surveys further north at Deepwater NP (24°19'S, 151°56'E) and Eurimbula NP (24°05'S, 151°42'E), which had also received heavy rain. Survey effort was concentrated in areas with habitat typical of *C. tinnula* (i.e., low-lying areas of sandy soil with heath, *Melaleuca* woodland and/or sedges). All sites were surveyed at night by listening for calls and searching with headlamps. Sites at Deepwater and Eurimbula NP were also visited by day. Climatic conditions under which surveys were conducted are summarised in Table 1.

Identification of *Crinia* spp. was based on morphology and/or call. Morphological characters used to distinguish between *Crinia* spp. were (1) belly colouration (white without speckling [*C.*

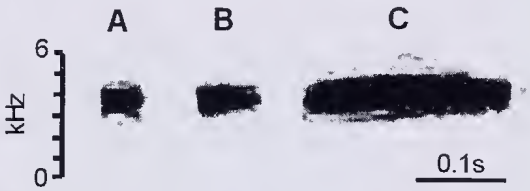

FIG. 1. Sound spectrograms showing advertisement calls of (A) male *C. tinnula* (QMJ80271) recorded at Littabella NP on 6.06.2002 (ambient [air] temperature = 19C); (B) male *C. tinnula* recorded at Karawatha Forest Park, Brisbane on 9.8.02 (ambient temperature = 18.5C); and (C) *Crinia parinsignifera* recorded at Karawatha Forest Park on 9.8.02 (ambient temperature = 18.5C). Calls of *C. tinnula* and *C. parinsignifera* were recorded using the same equipment as that used to record *C. tinnula* at Littabella NP. As these spectrograms show, calls of *C. tinnula* are of similar frequency but much shorter duration than that of *C. parinsignifera*. The advertisement call of *C. deserticola* (not shown here) is a double note (vs. single note in *C. tinnula* and *C. parinsignifera*) with a dominant frequency of 4kHz (see Liem & Ingram, 1977).

TABLE 1. Climatic conditions during surveys at Littabella, Deepwater and Eurimbula National Parks in June 2002. Air temperature was measured at ground level.

Site	Date	Cloud cover	Air temp. °C	Rainfall	Surface water
Littabella NP (1)	6.06.02	100%	19-20	light rain with occasional heavier showers	none
Littabella NP (2)	6.06.02	100%	19-20	light rain with occasional heavier showers	present
Deepwater NP	6.06.02	100%	-	overcast; intermittent light rain	present
Eurimbula NP	7.06.02	100%	20-21	overcast; rain in afternoon	present

deserticola] vs. grey or off-white with dark speckling [*C. tinnula* and *C. parinsignifera*]) and (2) presence/absence of a pale mid-ventral stripe down the throat and abdomen (present only in *C. tinnula*). In some *C. tinnula*, especially preserved specimens, the presence of a pale mid-ventral stripe may be difficult to discern making identification difficult. To allow positive identification of animals, calls of male *Crinia* were recorded using a Cardiod unidirectional microphone and Sony Walkman cassette-recorder. Advertisement calls of male *C. tinnula* and *C. parinsignifera* were also recorded at Karawatha Forest Park (Brisbane, southeast Qld) during winter 2002 for comparison with calls recorded at Littabella NP. Sound spectrograms of recorded calls were produced using the program Canary.

Animals identified as *C. tinnula*, based on morphology and/or call (see Fig. 1), were found at two sites in Litabella NP. At the first site (24°38'03.53"S, 152°02'52.22"E) two individuals were found along a firebreak through an area of wet heath, upslope from a drainage line. Despite substantial rain, there was no significant surface water at this site and no frogs were heard calling. Other frog species encountered/detected at this site included *Litoria nasuta* and *Limnodynastes terraereginae*. At the second site (24°36'32"S, 152°03'23"E), a sedge swamp with emergent *Melaleuca viridiflora*, male *C. tinnula* were found calling near water. Anuran species sympatric with *C. tinnula* at this site included: *Crinia deserticola*, *Pseudophryne major*, *P. raveni*, *Limnodynastes peronii*, *L. tasmaniensis*, *L. terraereginae*, *Litoria nasuta* and *L. fallax*. Voucher specimens were collected from both sites and subsequently lodged at the Queensland Museum (registration numbers QMJ80269-71).

At Deepwater NP a sizeable area of apparently suitable habitat was surveyed. Despite the presence of surface water, only *C. deserticola* were heard calling. The following night, at Eurimbula NP, several areas of apparently suitable habitat were surveyed. Here again only *C. deserticola* were found. Conditions were not dissimilar to those the previous night (see Table 1).

Based on these surveys the northern limit for *C. tinnula* would appear to be Littabella NP. *C. tinnula* could, however, occur further north in Deepwater NP. In the south of this national park is an area of wet heath with emergent *Melaleuca* subject to inundation which seems ideal for *C. tinnula*. Further surveys of this area are required to determine whether *C. tinnula* is present.

Littabella, Deepwater and Eurimbula National Parks contain habitat suitable not only for *C. tinnula* but also *Litoria olongburensis* and *Litoria freycineti* (both listed as vulnerable in Queensland). Surveys of these areas, however, did not reveal the presence of either species. The timing of surveys, however, may not have been suitable for detection of these 'acid' frog species.

LITERATURE CITED

CLARKE, J., HODGON, J., HORTON, P., HAZZARD, A., KAMPF, A., WALKER, C. & CLARK, S. 1998. Fauna Surveys of Littabella NP. (Internal report for Queensland Department of Environment).

HINES, H., MAHONY, M. & MCDONALD, K. 1999. An assessment of frog declines in wet subtropical Australia. Pp. 44-63. In Campbell, A. (ed.) Declines and disappearances of Australian frogs. (Environment Australia: Canberra).

LIEM, D.S. & INGRAM, G.J. 1977. Two new species of frogs (Anura: Myobatrachidae: Pelodryadidae) from Queensland and New South Wales. Victorian Naturalist 94: 255 –262.

A SECOND AUSTRALIAN SPECIES OF THE GONDWANAN STAG BEETLE GENUS *SPHAENOGNATHUS* BUQUET (COLEOPTERA: LUCANIDAE)

B.P. MOORE AND G.B. MONTEITH

Moore, B.P. & Monteith, G.B. 2004 06 30: A second Australian species of the Gondwanan stag beetle genus *Sphaenognathus* Buquet (Coleoptera: Lucanidae). *Memoirs of the Queensland Museum* **49**(2): 693-699. Brisbane. ISSN 0079-8835.

Sphaenognathus (Australognathus) munchowae sp. nov. is described from two high tablelands of central Queensland and is regarded as a sister species of *S. (A.) queenslandicus* Moore, known only from the rainforest of the Carbine Tableland in the north of the state. Information on the biology and habitat, including immature stages, of the new species is presented. ❑ *Insecta, Coleoptera, Lucanidae, Australia, stag beetle, biology.*

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The discovery, in 1973, of a single male of an Australian species of *Sphaenognathus* Buquet, living in high-altitude rainforest of northern Queensland, was an event of considerable zoogeographical significance, for hitherto, this genus of stag beetles was known only from the Neotropical region. Subsequently, when further males became available from the type locality (Mt Lewis on the Carbine Tableland), this species was described by one of us as *S. queenslandicus* (Moore, 1978) and was interpreted as being a Gondwanan relict.

DISCOVERY OF SECOND SPECIES

By strange coincidence, a dead female of an apparent second species of *Sphaenognathus* was also discovered in 1973, by a young bush-walker, Elizabeth Munchow, in open *Eucalyptus* woodland on the isolated Blackdown Tableland, inland from Rockhampton and some 950 km SSE of Mt Lewis. This enigmatic specimen was given to local collector Ernest Adams, who, following publication of *S. queenslandicus* in 1978, recognised its similarity to that species and donated it to the ANIC, Canberra. However, because the female of *S. queenslandicus* was then unknown, little informative comparison of the two populations was feasible.

Despite intensive search at Blackdown by several entomologists, no male from this southern population became available for study for many years. However, a second dead female was found, out of season, in May 1993, by a Queensland Museum party on the remote, high Consuelo Tableland in the Mt Moffat Section of Carnarvon National Park. In an attempt to get further specimens, three long-term, flight intercept traps, with 1.5m^2 panels, were installed at that locality by the Queensland Museum in September 1995, with the intention of operating them right through the summer season, during which emergence of adult beetles could be expected. The traps were cleared in November 1995 without success. At the final clearance, in late February 1996, one of the traps contained a pair of large adult *Sphaenognathus*, including the first available specimen of the critical male sex. Field search on the same occasion located a colony of larvae, of all stages, beneath a large rotten log, together with fragments of dead female adults. Fifty six living larvae were taken back to Brisbane, together with a large amount of the wood as food. Over the following 46 months, 6 males and 2 females, were reared from these larvae.

Following success with larval collection at Consuelo Tableland, GBM revisited Blackdown Tableland on 11-12 April 1996, and searched under logs. A single, 3rd instar larva, identical to those from Consuelo, was located but it died several months later without transforming.

From August 2001 to Feburary 2002, Queensland Parks and Wildlife Service staff surveyed fauna at 11 sites on the Consuelo Tableland. Small insect pitfall traps were operated continuously at all sites and flight intercept traps at 4 sites. Eight large dry pitfalls for vertebrates were operated at each site for a week in November and again in February. No *Sphaenognathus* were taken in the insect traps, but 6 living females were taken in the vertebrate pitfalls at 3 of the 11 sites during the February trap period. The absence of males may be explained by the more terrestrial habits of the females favouring their capture.

Study of these collections confirms that the Blackdown and Consuelo populations are identical and constitute a second Australian species of the genus, which is described below.

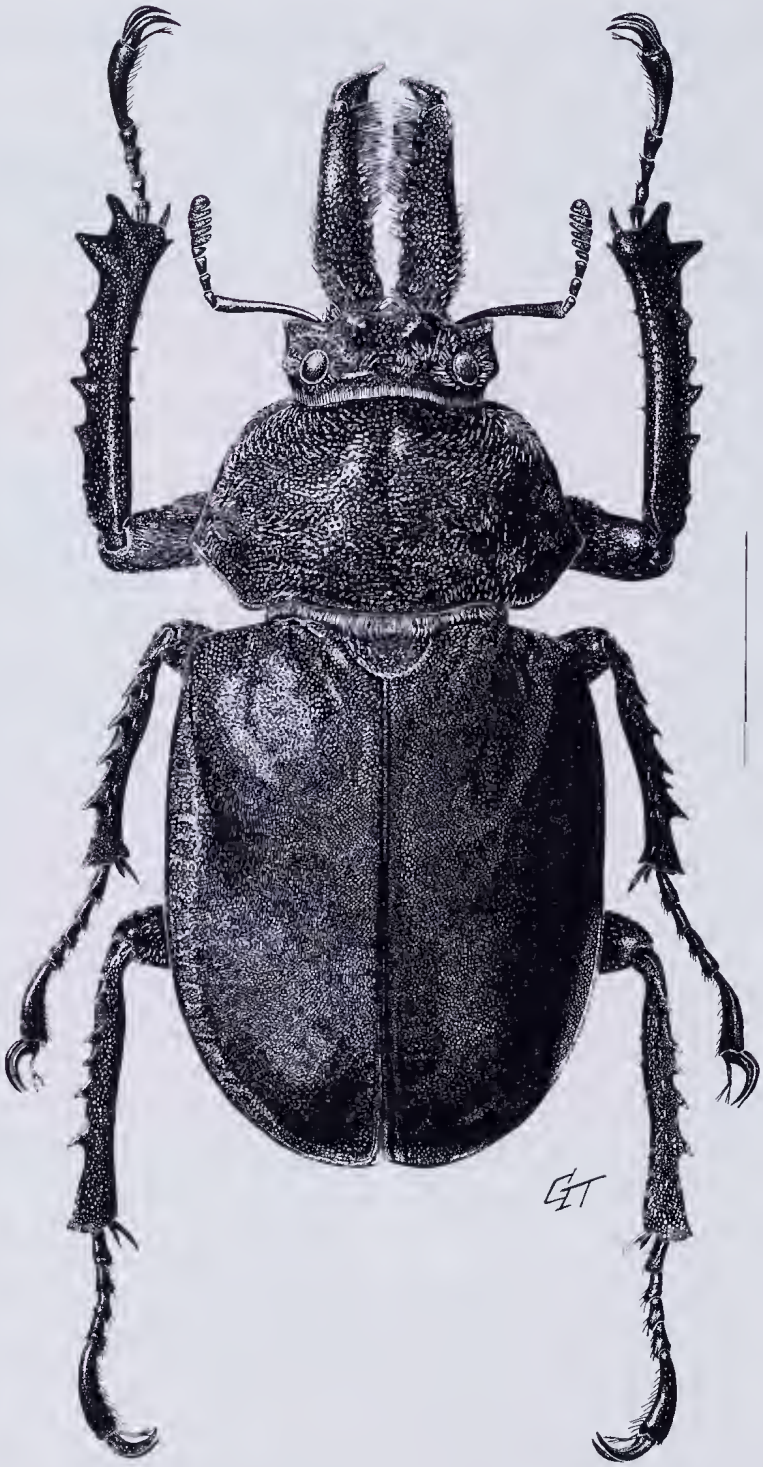

FIG. 1. *Sphaenognathus (Australognathus) munchowae* sp. nov., major male dorsal view, based on holotype. Scale line 10mm.

GENERIC PLACEMENT

Chalumeau & Brochier (1993) erected a new genus, *Australognathus*, for *S. queenslandicus* and described the female of the species from material provided by us. This classification is maintained in their subsequent synopsis of the group (Chalumeau & Brochier, 1995). However, as the Australian species differ from those from South America in only minor ways, essentially restricted to the male sex, we prefer to treat *Australognathus* as a subgenus of *Sphaenognathus*.

Abbreviations for specimen depositories are: ANIC, Australian National Insect Collection, Canberra; MDPI, Department of Primary Industries, Mareeba; QM, Queensland Museum, Brisbane.

Sphaenognathus (Australognathus) munchowae sp. nov.
(Figs 1-6)

ETYMOLOGY. Named for its discoverer, Elizabeth Munchow.

MATERIAL. CENTRAL QUEENSLAND. HOLOTYPE ♂, QMT108919, Mahogany Forest, Mt Moffatt NP, 24°56'S 148°04'E, 1200m, 25.xi.1995-25.ii.1996, flight intercept trap, G.B. Monteith (QM). PARATYPES, 1♀, same data as holotype (QM); 1♀, same locality, 24-26.ii.1996, G.B. Monteith (reconstructed from parts of dead specimen, QM); 6♂, 2♀, coll. as larvae same locality and date, emerged as adults as follows: 1♂, em. Mareeba, 14.ix.1998 (MDPI), 2♂, 2♀, em. Brisbane, x.1998 (QM), 1♂, em. Brisbane, 27.xi.1996, deformed, not paratype (QM), 2♂, em. Julatten, i. & xii.1999 (ANIC); 1♀, same locality, 29.v.1993, R. Sheridan (coll. as dead specimen, QM); 3♀, same locality, pitfall trap, Site 9, 11-20.ii.2002, C. Eddie (QM); 2♀, 2.2km SSW Peawaddy Gorge Lookout, 24°56'S 148°04'E, pitfall trap, Site 35, 11-20.ii.2002, C. Eddie (QM); 1♀, Foley's Spring, Mt Moffatt NP, 24°57'S 148°08', pitfall trap, Site 32, 11-20.ii.2002, C. Eddie (QM); 1♀, Blackdown Tableland, ii.1973, E. Munchow (coll. as dead specimen, ANIC).

DESCRIPTION. *Male* (Figs 1, 2B, 3, 4A-B, 5A). Entirely dark, pitchy-black, without metallic tints. Upperside matt; underside with sparse greyish pubescence. Length (including mandibles), 34-48mm (HT, 48mm); max. width 15-19mm (HT, 19mm).

Head. Small, very transverse, rugosely punctate and thinly pilose, except on vertex and frontal bullae; canthi sinuate, their anterior angles sharp and prominent, their posterior angles obtuse but well marked; mandibles (Figs 1, 2B, 3) slender, porrect, somewhat longer than pronotum, the left (length, 6-11 mm; HT, 11mm) a little longer than the right, both strongly (in holotype, abruptly) downcurved in lateral view, with apices acute and inturned and with two prominent, closely approximate teeth internally, rather strongly

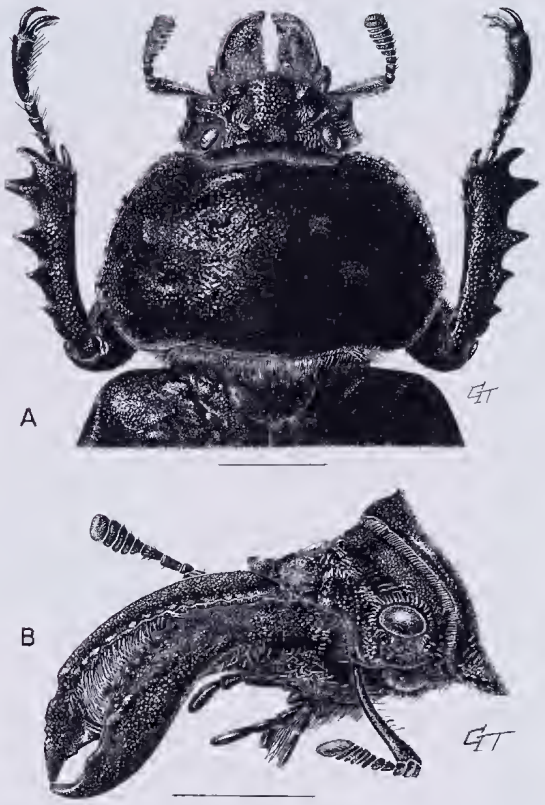

FIG. 2. *Sphaenognathus (Australognathus) munchowae* sp. nov., A, female foreparts; B, major male head and mandibles in oblique left lateral view. Scale lines 5mm.

pilose beneath the denticulate upper internal carina; mandibular dorsal carina obsolete except near apex; lower internal carina obsolete except near base, there terminating in a small, subconical, sometimes bifid, ventral tooth; mentum entire, trapezoidal; eyes subcircular dorsally and ventrally; antennal club clearly 6-segmented.

Pronotum. Gibbous, transverse (HT, 17 × 10mm), broadest at basal quarter, where margins subdentate; entire upper surface coarsely and irregularly punctate, sparsely pubescent, except on disc.

Elytra. Broad, rather convex near scutellum, matt and almost smooth, glabrous; humeri subangular, swollen; scutellum small, transverse, finely rugose; hindwings fully developed.

Legs. Slender; fore-tibiae slightly arcuate, strongly bidentate apically, outer and ventral margins irregularly denticulate; mid- and hind-tibiae almost straight, externally irregularly but acutely multidentate; tarsi long, shining; onychium setose beneath.

Aedeagus (Fig. 4A,B). Well sclerotised; penis with characteristic sclerotisation pattern; everted portion with long flagellum; parameres bare.

Female (Figs 2A, 5A). Similar in colour to male but upper surface darker and more shiny; body broader; *head* with mandibles short, outwardly regularly curved, inwardly sinuate or vaguely dentate; vertex subtuberculate; *pronotum* more transverse, with lateral angles less marked; *elytral* sculpture more rugose; *tibiae* shorter, broader, dentition stronger, especially sharp on mid- and hind-tibiae; fore tibiae without ventral dentition; spermatheca (Fig. 4C) well sclerotised, constricted in middle, at entry-point of accessory gland; styli short, ovoid and pilose as in most other species of the genus (Bartolozzi et al., 1992). Length (including mandibles), 35-44.6mm; max. width, 13-22.5mm.

Variation. Lengths of mandibles in minor males only some 55% of those of holotype, less down-curved in lateral view and with the upper internal carina less marked; anterior angles of canthi sometimes truncate; tibial teeth variable in numbers in both sexes, often showing lateral asymmetry.

REMARKS. Although evidently closely related to *S. (A.) queenslandicus*, the new species differs in its larger size, uniform dark colour, unicolorous tibiae with much stronger dentition in both sexes, its angular and more prominent canthi and its clearly 6-segmented antennal club (in *S. queenslandicus* antennomere 4 is slightly expanded). Major males of *S. munchowae* have longer and more slender mandibles than have yet been seen in any males of *S. queenslandicus*. In all males of the new species, the mandibles are much less expanded basally, and show different dentition. The penis in *S. munchowae* shows a distinct sclerotisation pattern and bears a longer flagellum.

HABITAT AND DISTRIBUTION. Geologically, much of inland central Queensland is sandstone, laid down under Mesozoic seas. The present uplifted surface has been considerably eroded leaving many isolated, residual plateaus representing fragments of the original flat terrain. The two localities where *Sphaenognathus munchowae* has been discovered, Blackdown and Consuelo Tablelands, are the largest and highest of these residual plateaus. Blackdown reaches 900 m altitude and lies 180 km from the coast at 23°45'S. Consuelo is 150km SSW of Blackdown, reaches 1200m, and lies 370km inland at 25°00'S.

Both areas are quite remote and have been biologically explored comparatively recently. The environment of both is cool, wet and heavily

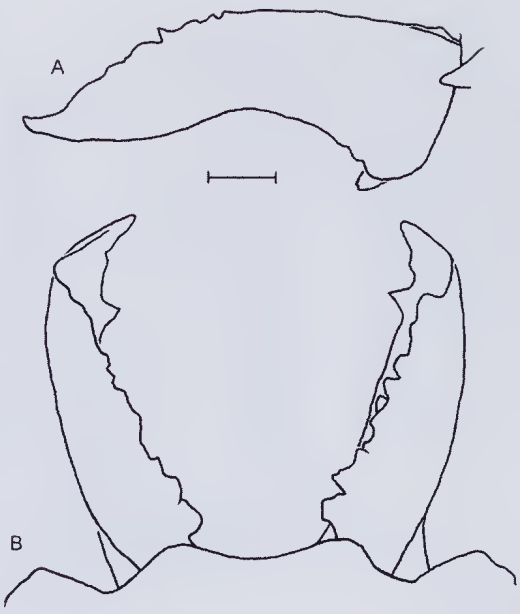

FIG. 3. *Sphaenognathus (Australognathus) munchowae* sp.nov., mandibles of minor male. A, lateral view; B, dorsal view. Scale line, 1mm.

forested in comparison with the hot, dry, sparsely vegetated surrounding lowlands (Henderson, 1976). Botanically and entomologically, these two tablelands have a strong refugial character, supporting species which differ from the surrounding lowlands, including many endemics and many highly disjunct populations, particularly of species known otherwise from further south in Australia (Atkins, 1974; Henderson, 1976; Monteith & Yeates, 1988; Rentz, 1986). These features support our view that the two populations of *S. munchowae* are remnants of a more widespread distribution dating back to Gondwanan times when Australia was in contact with southern land masses and before erosion isolated the current plateaus.

At each locality, records of the beetle are from the highest rainfall sectors of the plateau, where the eucalypt forest habitat is tallest. At Blackdown this lies at the northeast corner of the tableland. At Consuelo this lies at the SW corner where a basalt soil overlay to the sandstone supports a dense stand of *Eucalyptus nitens*, known locally as the 'Mahogany Forest'. This suggests that the range of the species is much smaller than that of the entire plateaus and thus may be vulnerable to collecting. However both areas lie entirely within protected reserves.

The eucalypt forest habitat of the new species contrasts strongly with the high altitude tropical

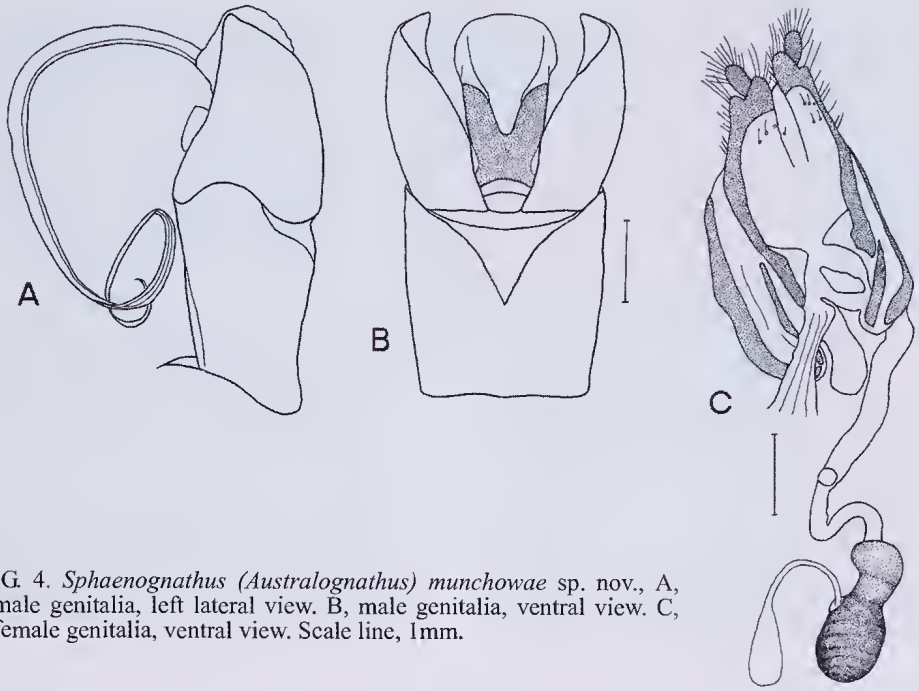

FIG. 4. *Sphaenognathus (Australognathus) munchowae* sp. nov., A, male genitalia, left lateral view. B, male genitalia, ventral view. C, female genitalia, ventral view. Scale line, 1mm.

rainforest habitat of *S. queenslandicus* in north Queensland. A few additional specimens of this species have been taken (Chalumeau & Brochier, 1993) since its original description. All are from within a radius of about 20km on the Carbine Tableland, a mountain massif known for endemic and Gondwanan insects (Monteith, 1980; Yeates et al., 2002)

LIFE HISTORY NOTES. Details of life history and morphology of immature stages are given for 6 species of Peruvian *Sphaenognathus* by Onore (1994). These species are atypical among Lucanidae in that larvae live freely in the soil, rather than in rotten wood. Several species are described as coating their abdominal segments 3-5 with soil. Although all life history stages of *S. munchowae* were collected, only preliminary comments on their morphology will be made in this paper.

Adult Seasonality. No living adults of *S. munchowae* have been directly hand collected, so information on activity periods derives from trap catches at Consuelo Tableland. Traps were operated continuously from spring to late summer in years 1995/96 and 2001/02. During the first series a male and female were taken between Nov 25 and Feb 24. Since both were in the same trap, and appeared quite fresh, it can be speculated that they were trapped in the latter part of the trap period and they may have been a courting pair. During the second trap series six females were taken, all between 11-20 February. These two trap catches would suggest late summer adult emergence. However all artificially reared larvae moulted to adults during spring-early summer (September-January). The explanation for this apparent anomaly is probably that, in the field, adults remain in their subterranean pupal chambers until summer rains, highly sporadic in the region, trigger emergence and mating.

Larval Habitat, Behaviour and Seasonality. Unlike the South American species (Onore, 1994) all larvae of *S. munchowae* have been taken feeding on wood of very old, rotten logs deeply embedded in the ground. At Consuelo, logs were of *Eucalyptus* trees; at Blackdown the single occurrence was under a small *Casuarina* log. Unlike most lucanid larvae which live within the wood, *S. munchowae* larvae live in a chamber beneath the log, lying on the soil and feeding on the underside of the log above them. Small larvae sometimes burrow partly into the wood but large larvae are invariably either partly embedded in the soil surface or free in the feeding chamber where they lie on a bed of their distinctive, hard, circular, flattened faecal pellets which are deeply notched on one side (Fig. 5B,D).

Larvae are very long-lived and large logs clearly support many generations of larvae over many years. All larval stages may be present

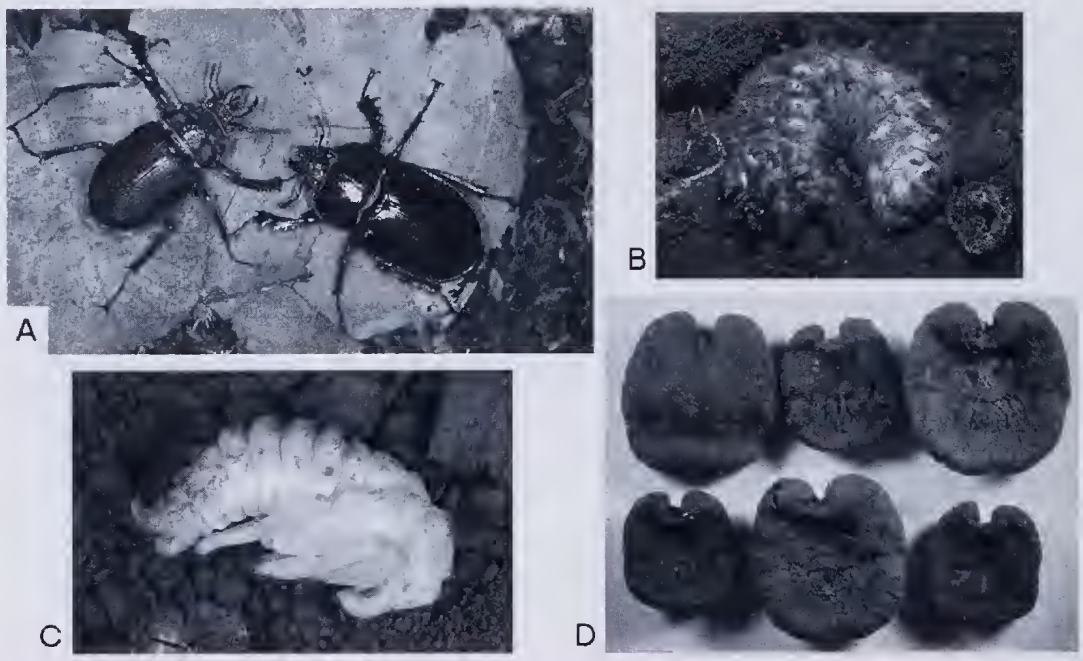

FIG. 5. *Sphaenognathus (Australognathus) munchowae* sp. nov., A, living minor male (left) and female, reared from Consuelo Tableland larvae (photo Gary Cranitch, QM); B, third instar larva from Consuelo Tableland (photo Steve Wilson); C, male pupa, lateral view (photo Paul Zborowski); D, faecal pellets of second (small) and third (large) instar larvae.

synchronously. From the large log investigated at Consuelo on February 25, 1996, 3 eggs, 6 first instars, 23 second instars and 27 third (final) instar larvae were collected. These live larvae were returned to Brisbane to attempt rearing of further adults. To provide a range of climates and breeding expertise, some were sent to colleagues in Mareeba, Julatten and Innisfail (tropical) and Mt Glorious (subtropical), with the bulk of them retained in Brisbane (subtropical). Larvae were kept in individual jars and fed readily on wood from the original log. Eight months later, one Brisbane larva formed a pupal cell in early October, pupated on October 10 and emerged as an adult male on November 27. No further metamorphosis occurred for another two years until September, 1998, when some larvae in Brisbane and Mareeba began to pupate leading to emergences in October of 4 females in Brisbane and 1 male in Mareeba. Two more males at Julatten emerged in January and December, 1999. Since the last Julatten larva was already final instar when first collected 46 months earlier it appears that larval life is very lengthy. All other larvae eventually succumbed, mostly to fungal attack. Preserved specimens of all instars are held at QM and final instars are in ANIC.

Eggs. White, oval, and measure 3.8 × 2.8mm. Of the three collected in February, 1996, one hatched within a week and the others, with larvae visible inside, were preserved.

Larvae. Easily separated from other Australian lucanid larvae by their coarsely hairy bodies (Fig. 5B) and the two prominent, oval, anal pads, both characters described by Onore (1994) for *Sphaenognathus.* First and second instars are clean and white but third instars have their whole body coated with a thin layer of soil, an accentuation of the situation described by Onore for South American species. Dimensions for larvae of *S. munchowae* are: first instar, max. length 15mm, head capsule width 2.6-2.7mm; second instar, length, 35mm, head capsule, 5.2-5.6mm; third instar, length 65mm, head capsule, 9.2-10.6mm.

Larval Stridulation. Larvae have the normal lucanid stridulatory mechanism of a toothed plectrum on the hind leg which moves against a stridulitrum ridge on the mid coxa. Onore (1994) notes that the sound produced by South American species is not audible to the ear, but can be felt through the hand. He speculates that it may be used to reinforce spacing between larvae in

soil. The Australian larvae also stridulate vigorously when handled and are also inaudible to the ear but detectable in the hand. In May 1997, recordings of stridulating larvae were made, showing clear substrate-borne pulses of vibrations (Fig. 6), with legs on each side of the body operating alternately. Stridulation in captive larvae was only triggered by contact which indicates it may be a soil-borne proximity signal as suggested by Onore (1994).

Pupation. Captive larvae always burrowed to the bottom of the jar before forming a pupal cell. This suggests that in the field they pupate deeper within the soil beneath their feeding log. Pupae (Fig. 5C) lie on their back in the pupal chamber, supported above the substrate on two swellings on the pronotum and a series of five raised transverse ridges, each with inflected margins, which run across abdominal terga 1-5. The pronotal swellings have equivalents in the pupa of the Peruvian *S. lindenii* described by Onore (1994) but the transverse abdominal ridges of *S. munchowae* do not.

Life History of S. queenslandicus. With knowledge of the breeding behaviour of *S. munchowae*, the authors and Mr Jack Hasenpusch have searched intensively on several occasions at the Mt Lewis type locality of the North Queensland species for its immature stages, without success.

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We are grateful to the following people. Geoff Thompson, created the fine textured illustrations in Figs 1-3. Elizabeth Munchow, as a schoolgirl on an outing to Blackdown 31 years ago, collected the first specimen of the new species, and Ernest Adams passed it to the ANIC. Hannelore Hoch and Manfred Asche, of the Humboldt Museum in Berlin, recorded larval stridulation during a visit to Brisbane. Queensland Parks and Wildlife Service issued permits to enable collection of the species in reserves and Craig Eddie, of that Service, collected stag beetles for the Queensland Museum during their vertebrate survey at Consuelo in 2001-02. Chris Burwell and Susan Wright helped with collecting at Consuelo in 1996. Ross Storey, Jack Hasenpusch and Tony Hiller all assisted in attempts to rear adults from the intractable larvae of the new species.

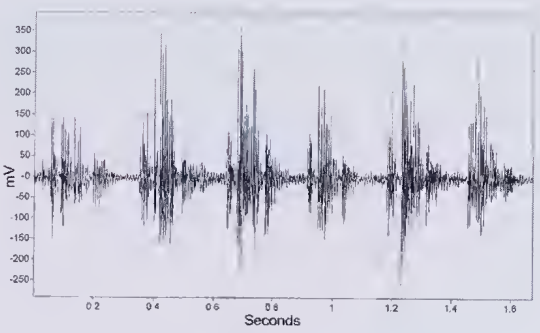

FIG. 6. *Sphaenognathus (Australognathus) munchowae* sp. nov., sonagram of stridulation of third instar larva (courtesy, Hannelore Hoch).

LITERATURE CITED

ATKINS, A.F. 1974. Butterflies of Expedition Range, central Queensland. Victorian Entomologist 4: 9-14.

BARTOLOZZI, L., BOMANS, H.E. & ONORE, G. 1992. Contributo alla conoscenza dei Lucanidae dell'Ecuador (Insecta, Coleoptera). Frustula entomologica n.s. 14: 143-246.

CHALUMEAU, F. & BROCHIER, B. 1993. Un nouveau genre de Chiasognathinae australien. Bulletin de la Société des Sciences Naturelles 79: 16-17.

1995. Les Chiasognathinae: genres, sous-genres et synonymies (Coleoptera: Lucanidae). Bulletin de la Société des Sciences Naturelles 83: 18-24.

HENDERSON, R.J.F. 1976. History and floristics of the Blackdown Tableland, central Queensland. Queensland Naturalist 21: 119-124.

MONTEITH, G.B. 1980. Relationships of the genera of Chinamyersiinae (Hemiptera:Aradidae), with description of a relict species from mountains of north Queensland. Pacific Insects 21: 275-285.

MONTEITH, G.B. & YEATES, D.K. 1988. Butterflies of Mount Moffatt and Carnarvon National Parks, Queensland. Queensland Naturalist 28: 14-22.

MOORE, B.P. 1978. A new Australian stag beetle (Coleoptera: Lucanidae) with neotropical affinities. Journal of the Australian Entomological Society 17: 99-103.

ONORE, G. 1994. Description of the immature stages of six species of *Sphaenognathus* with comparative notes on phylogeny and natural history (Insecta: Coleoptera: Lucanidae). Annals of the Carnegie Museum 63(1): 77-99.

RENTZ, D.C.F. 1986. The orthopteran family Cooloolidae, including description of two new species and observations on biology and food preferences. Systematic Entomology 11(2): 231-246.

YEATES, D.K., BOUCHARD, P. & MONTEITH, G.B. 2002. Patterns and levels of endemism in the Australian Wet Tropics rainforest: evidence from flightless insects. Invertebrate Systematics 16: 605-619.

FRUGIVORY IN THE BLACK MOUNTAIN RAINBOW-SKINK, *CARLIA SCIRTETIS* INGRAM AND COVACEVICH, 1980. *Memoirs of the Queensland Museum 49(2): 700. 2004:-* The Black Mountain Rainbow-skink, *Carlia scirtetis*, is a small-medium sized saxicolous scincid (snout-vent length up to 70mm, mass 4-6g, Goodman, unpubl. data) restricted to the 6km^2 boulder jumble habitat of the Black Trevethan Range, NE Queensland (Ingram & Covacevich, 1980, 1989). Like almost all skinks of this size, *C. scirtetis* is presumed to have a diet composed almost entirely of terrestrial invertebrate prey (Brown, 1983; Ingram & Covacevich, 1980; Greer, 1989), with the possibility of opportunistic taking of aerial invertebrates. Black Mountain is comprised almost entirely of granitic boulders that range in size from 0.5-1200m^3 (most >8m^3) and has a very sparse vegetation. Therefore, I assume that invertebrate prey is likely to be depauperate. Here, I report on the incidence of frugivory by *C. scirtetis* and suggest that figs may act as an important food supplement. Herbivory is usually associated with larger lizards (>100g; King, 1996) and, hence, seems an unlikely dietary option for this species, with a body weight of 4-6g.

While collecting *C. scirtetis* on the northern side of Black Mountain (25-29/11/2000), adult and sub-adult individuals were observed feeding on the ripe fruit of the native fig, *Ficus obliqua* var. *obliqua*, which grows in isolated sites on Black Mountain (Werren & Trenerry, 1990). Ripe fruit were orange-red, compared to green when unripe (Cooper & Cooper, 1994). Due to the relatively small size of this fig, *C. scirtetis* appeared to consume each fruit whole with little chewing. Further, possibly due to the strict saxicolous habits of *C. scirtetis*, individuals were only observed accessing fruit from branches that closely overhung boulders (Ingram & Covacevich, 1980; 1989). No individuals were observed climbing trunk or branches to access fruit. To determine the extent to which the skinks were feeding on fruit, a sample of recently collected male and female sub-adults and adults (N=8) were monitored for scat production. All individuals were maintained individually in captivity in plastic boxes (350 × 130 × 100mm) for up to 5 weeks, prior to release at their site of capture (QPWS Scientific Purposes Permit No. F1/000253/99/SAA). Each individual was checked regularly throughout the day, and all fresh scats were collected and dissected to estimate the proportion of *Ficus* seeds present. An examination of all scats produced within the first 24 hours indicated that during November the scats of *C. scirtetis* consist of approximately 70-80% by volume of *F. obliqua* var. *obliqua* seeds. Examination of scats produced after the first 24 hours and up to three days following capture indicated that *Ficus* seeds were still present within scats of *C. scirtetis*, suggesting that these seeds remain within the digestive tract for a number of days following ingestion.

Like most skinks in northern Australia, members of *Carlia* are 'income' breeders and produce a series of clutches during the wet-season (October – February; Wilhoft & Reiter, 1965; James & Shine, 1985; Clerk and Alford, 1993). Thus, these clutches are likely to be produced directly from recently obtained resources. As a consequence any additional resources that are obtained are also likely to be allocated predominantly to reproduction. The period of fruiting for the fig (November – June; Cooper & Cooper, 1994) encompasses and extends beyond the period of clutch production typical for *Carlia* spp. (November – March) in this region (Wilhoft, 1963; James & Shine, 1988) including *C. scirtetis* (Goodman unpubl. data.). Thus, these additional resources and the extended fruiting season may help to reduce costs of reproduction in *C. scirtetis* (i.e., detriment to body condition) that are likely to be incurred (Shine, 1980; Schwarzkopf, 1993) by reproducing female lizards, particularly in more nutritionally stressful environments (Schwarzkopf, 1994). Therefore, diet supplementation may enable *C. scirtetis* to make a greater reproductive investment than if limited solely to invertebrate prey, and may also facilitate a more rapid recovery from reproduction.

The high proportion of fig seeds in *C. scirtetis* scats suggests that it consumes figs in substantial proportions and may act as a disperser of fig seeds on Black Mountain. Other vectors for seed dispersal on Black Mountain are birds and bats (Herrera, 1984; Howe & Smallwood, 1982). Research on fruit ingestion by *Hoplodactylus maculatus*, a gecko of similar size (SVL to 75mm; Whitaker, 1982) indicates that a high proportion of ingested fruit germinate successfully (72%). Further, geckos typically deposited seeds in microhabitats suitable for successful germination (Wotton, 2002). Thus, *C. scirtetis* may be significant in dispersal and establishment of *F. obliqua* var. *obliqua* as the dominant tree species of the Black Mountain boulder jumbles.

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Literature Cited

BROWN, G.W. 1983. Comparative feeding ecology of south-eastern Australian scincids. Unpubl. PhD thesis, La Trobe University, Melbourne.

CLERK, R.B. & ALFORD, R.A. 1993. Reproductive biology of four species of tropical Australian lizards and comments on the factors regulating lizard reproductive cycles. Journal of Herpetology 27: 400-406.

COOPER, W. & COOPER, W.T. 1994. Fruits of the rain forest. (RD Press: Chatswood, Sydney).

GREER, A.E. 1980. Critical thermal maximum temperatures in Australian lizards: their ecological and evolutionary significance. Australian Journal of Zoology 28: 91-102.

1989. The biology and evolution of Australian lizards. (Surrey Beatty and Sons: Chipping Norton, Sydney).

HERRERA, C.M. 1984. Adaptations to frugivory of Mediteranean avian seed disperers. Ecology 65: 609-617.

HOWE, H.F. & SMALLWOOD, J. 1982. Ecology of seed dispersal. Annual Review of Ecologists and Systematists 13: 201-228.

INGRAM, G.J. & COVACEVICH, J. 1980. Two new Lygosomine skinks endemic to Cape York Peninsula. Pp. 45-48. In Stevens, N.C. & Bailey, A. (eds) Contemporary Cape York. (Royal Society of Queensland: Brisbane).

1989. Revision of the genus *Carlia* (Reptilia, Scincidae) in Australia with comments on *Carlia bicarinata* of New Guinea. Memoirs of the Queensland Museum 27: 443-490

JAMES, C.D. & SHINE, R. 1985. The seasonal timing of reproduction: a tropical-temperate comparison in Australian lizards. Oecologia 67: 464-474.

KING, G. 1996. Reptiles and herbivory. (Chapman & Hall: London).

SCHWARZKOPF, L. 1993. Costs of reproduction in water skinks. Ecology 74: 1970-1981.

1994. Measuring trade-offs: a review of studies of costs of reproduction in lizards. Pp. 1-28. In Vitt, L.J. & Pianka, E.R. (eds) Lizard ecology: historical and experimental perspectives. (Princeton University Press: Princeton).

SHINE, R. 1980. "Costs" of reproduction in reptiles. Oecologia 46: 92-100.

WERREN, G. & TRENERRY, M. 1990. Kalkajaka: the mountains of death or life? Heritage Australia 9(3): 42-45.

WILHOFT, D. 1963. Reproduction in the tropical Australian skink, *Leiopisma rhomboidalis*. American Midland Naturalist 70: 442-461.

WOTTON, D. M. 2002. Effectiveness of the common gecko (*Hoplodactylus maculatus*) as a seed disperser on Mana Island, New Zealand. New Zealand Journal of Botany 40: 639-647.

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OCCURRENCE OF MYCOBIOTA IN EASTERN AUSTRALIAN SEA TURTLE NESTS

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Phillott, A.D., Parmenter, C.J. & Limpus, C.J. 2004 06 30: Occurrence of mycobiota in eastern Australian sea turtle nests. *Memoirs of the Queensland Museum* **49**(2): 701-703. Brisbane. ISSN 0079-8835.

Major loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) sea turtle rookeries in eastern Australia were surveyed for the presence of fungi in turtle nests. While the fungi Fusarium oxysporum, F. solani and *Pseudallescheria boydii* were not universally present, they were isolated from the exterior of failed eggs of all turtle species and at all rookeries. Predominant fungi species varied spatially and temporally. ❑ *Sea turtle, egg, nest, fungi.*

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Globally, fungi have been described from the exterior and/or embryonic tissue of several species of sea turtle eggs (Table 1). *Fusarium oxysporum* Schlecht., *F. solani* (Mart.) Sacc. and *Pseudallescheria boydii* Negroni & Fischer have been identified from the exterior of failed eggs in sea turtle nests at Heron Island (Phillott et al., 2001). There have been no studies to determine the identity of fungi from failed eggs on turtle rookeries along a single coastline.

Heron Island (23°26'S, 151°55'E), Wreck Island (23°21'S, 151°57'E), Peak Island (23°20.5'S, 150°56'E), Milman Island (11°10'S, 143°00'E) and Mon Repos Conservation Park (24°48'S, 152°27'E) are major rookeries for the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles. These were surveyed in the 1996/97-1998/99 turtle nesting seasons (Table 2). Nests were located after hatchling emergence and excavated by hand to determine hatch success. A single unhatched egg that appeared by visual inspection to be colonised by fungus was taken from some nests (Table 2) and swabbed using MW170 TRANSTUBE®, Amies Clear Media and refrigerated at 3-5°C. Fungal swabs were incubated on half-strength Potato Dextrose Agar with $0.05gL^{-1}$ chloramphenicol to inhibit bacterial growth and then subcultured onto a range of media (e.g. Potato Dextrose Agar, Nutrient Agar, Carnation Leaf Agar) as required for identification. Identification of species not included by Booth (1971) and Seifert (1996) was confirmed by Professor D.E. Ellis. Voucher specimens were lodged with the Queensland Department of Primary Industries (Accession Numbers: *F. oxysporum* BRIP 28368, *F. solani* BRIP 28369, *P. boydii* BRIP 28370).

F. oxysporum, *F. solani* and *P. boydii* were isolated from sea turtle nests at all rookeries investigated (Table 2). The proportion of nests containing each fungal species varied between rookeries and, at Heron I. (the only rookery to be sampled in multiple years), between nesting seasons. Most samples were of single isolates, however 6.54% of all swabs revealed mixed cultures (1 *F. oxysporum* + *F. solani*; 2 *F. oxysporum* + *P. boydii*; 4 *F. solani* + *P. boydii*). While individual rookery/species census data often show absence of a particular fungus, all fungi were recorded from all turtle species.

As all 3 of the mycobiota isolated from Heron I. (Phillott et al., 2001) are common soil saprophytes, their presence in nests at other turtle rookeries in eastern Australia is not surprising. The temporal variation in predominant fungi observed at Heron I. (1996: *F. solani*; 1997: *P. boydii*) suggests that spatial differences in species composition cannot be solely attributed to geographic location, as it may equally have been influenced by environmental factors (e.g. hydric and thermal) and/or temporal variation.

A comparison of rainfall distribution and volume (1996: 237mm; 1997: 183mm), and air temperature (± SD 1996: max. 29.8±1.7°C, min. 23.1±1.6°C; 1997: max. 30.9±2.0°C, min. 24.0±1.9°C; beach temperature data not available), differed at Heron I. over the November to February sampling period between the 2 seasons. This may have contributed to the change in dominant nest mycobiota, as *F. solani* is more prevalent in areas with relatively high rainfall and low temperature (Burgess &

TABLE 1. Records of fungi associated with failed sea turtle eggs.

Turtle	Rookery	Isolate	Source
Green *Chelonia mydas*	-	*Aspergillus*	Solomon & Baird, 1980
Kemp's Ridley *Lepidochelys kempii*	-	*Fusarium*	Wyneken et al., 1988
Leatherback *Dermochelys coriacea*	St Croix, U.S. Virgin Islands	*Fusarium*	Eckert & Eckert, 1990
Loggerhead *Caretta caretta*	Göksu Delta, Turkey	*Mucor*	Peters et al., 1994
Olive Ridley *Lepidochelys olivacea*	Nancite, Costa Rica	*Allescheria*, *Aspergillus*, *Cunninghamella*, *Gliocladiopsis*, *Fusarium*, *Homodendrum*, *Saksenaea*	Mo et al., 1990
	Naranjo, Nancite, Costa Rica	*Fusarium*, *Monosporium*	Acuña-Mesén, 1992

Summerell, 1992). The germination rate and hyphal growth of all 3 fungi at varying hydric and thermal microclimatic conditions (experienced within natural sea turtle nests) is under further investigation.

Loggerhead turtle nesting populations in Queensland are in rapid decline (50-80% over 10-15yrs dependent on study site: Limpus & Reimer, 1994). Loggerhead nesting in the south Pacific Ocean occurs almost entirely in the southern Great Barrier Reef (the most significant being at Wreck I.) and Bundaberg coastline (including Mon Repos Conservation Park: Limpus, 1985). However loggerhead nests demonstrate high mortality (and associated fungal presence) on Wreck and Heron Islands when compared with green turtle nests at the same location, or loggerhead turtle nests on the adjacent mainland (Limpus et al., 1983; Phillott, 2002). Determining the role of fungi as an opportunistic contaminant of failed turtle eggs or infectant of living embryonic tissue is, therefore, of great conservation importance.

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LITERATURE CITED

ACUÑA-MESÉN, R.A. 1992. *Monosporium apiospermum* Saccardo (Fungi, Deuteromycetes), asociado a los huevos de la tortuga marina *Lepidochelys olivacea* (Eschscholtz 1829) en Costa Rica. Brenesia 38: 159-162.

BOOTH, C. 1971. The genus *Fusarium*. (Commonwealth Mycological Institute: Kew).

BURGESS, L.W. & SUMMERELL, B.A. 1992. Mycogeography of *Fusarium*: survey of *Fusarium* species in subtropical and semi-arid grassland soils from Queensland, Australia. Mycological Research 96: 780-784.

ECKERT, K.L. & ECKERT, S.A. 1990. Embryo mortality and hatch success in *in situ* and translocated leatherback sea turtle *Dermochelys coriacea* eggs. Biological Conservation 53: 37-46.

LIMPUS, C.J. 1985. A study of the Loggerhead Turtle, *Caretta caretta*, in Eastern Australia. Unpubl. PhD thesis, University of Queensland, St Lucia.

LIMPUS, C.J. & REIMER, D. 1994. The loggerhead turtle, *Caretta caretta*, in Queensland: a population in decline. Pp. 34-54. In James, R. (ed.) Proceedings of the Australian Marine Turtle Conservation Workshop, November 1990. (Australian Nature Conservation Agency: Canberra).

LIMPUS, C.J., REED, P. & MILLER, J.D. 1983. Islands and turtles. The influence of choice of nesting beach on sex ratio. Pp. 397-402. In Baker, J.T., Sammarco, P.W. & Stark, K.P. (eds) Proceedings of the Inaugural Great Barrier Reef Conference. (JCU Press: Townsville).

MO, C.L., SALAS, I. & CABALLERO, M. 1990. Are fungi and bacteria responsible for olive ridley's egg loss? Pp. 249-252. In Richardson, T.H., Richardson, J.I. & Donnelly, M. (comps) Proceedings of the 10th Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278.

PETERS, A., VERHOEVEN, K.J.F. & STRIJBOSCH, H. 1994. Hatching and emergence in the Turkish Mediterranean loggerhead turtle, *Caretta caretta*: a natural cause for egg and hatchling failure. Herpetologica 50: 369-373.

TABLE 2. Spatial and temporal variation in fungal presence in sea turtle nests.

Rookery, Season	Turtle	# Nests Excavated	# Nests Swabbed	% Nests		
				F. oxysporum	*F. solani*	*P. boydii*
Heron I. 1996/97	Green	86	22	22.7	63.6	13.6
	Loggerhead	2	2	0.0	100.0	0.0
Heron I. 1997/98	Green	108	19	5.0	5.0	100.0
	Loggerhead	5	3	0.0	0.0	100.0
Milman I. 1998/99	Green	7	5	40.0	60.0	0.0
	Hawksbill	32	8	12.5	75.0	12.5
Mon Repos 1998/99	Loggerhead	12	5	20.0	100.0	20.0
Peak I. 1998/99	Flatback	44	16	12.5	62.5	25.0
Wreck I. 1998/99	Green	39	16	18.8	62.5	37.5
	Loggerhead	7	4	50.0	50.0	25.0

PHILLOTT, A.D. 2002. Fungal colonisation of sea turtle nests in Eastern Australia. Unpubl. PhD thesis, Central Queensland University, Rockhampton, Queensland.

PHILLOTT, A.D., PARMENTER, C.J. & LIMPUS, C.J. 2001. Mycoflora identified from failed green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtle eggs at Heron Island, Australia. Chelonian Conservation and Biology 4: 170-172.

SEIFERT, K. 1996. FusKey: Fusarium Interactive Key. http://www.res.agr.ca/brd/fusarium.

SOLOMON, S.E. & BAIRD, T. 1980. The effect of fungal penetration on the eggshell of the green turtle. Pp. 434-435. In Brederoo, P. & de Priester, W. (eds) Proceedings of the Seventh European Congress on Electron Microscopy. (7th European Congress on Electron Microscopy Foundation: Leiden).

WYNEKEN, J., BURKE, T.J., SALMON, M. & PEDERSON, D.K. 1988. Egg failure in natural and relocated sea turtle nests. Journal of Herpetology 22: 88-96.

THE INFLUENCE OF LIGHT PHASE AND PREDATORS ON THE BEHAVIOUR OF SWAMP CRAYFISH. *Memoirs of the Queensland Museum 49(2): 704. 2004:-* *Tenuibranchiurus glypticus* (Riek, 1969) is a little studied freshwater crayfish with a distribution restricted to wallum swamps along the SE coast of Queensland. Harding & Williamson (2003) found that *T. glypticus* were more likely to be caught among sedges than in the open areas of the pools they occupy. One possible reason for this association is predator avoidance. This report describes the response of *T. glypticus* to visual and chemical cues from potential predators in laboratory conditions. The experiment examined whether the presence of a predator and light phase affected the total amount of time and the number of times that *T. glypticus* spent away from the refuge provided by sedges.

Experiments were conducted in four glass fish tanks (40 × 40 × 20cm) arranged in a block so that all four tanks were in the field of view of an overhead video recorder. Opaque partitions created visual barriers between tanks. A clear, perforated plexiglass divider separated each tank into two equal sized chambers (i.e. a predator half and a crayfish half). Approximately half of one chamber in each tank was planted with sedges to provide a refuge for *T. glypticus*.

Tanks were set up in a constant temperature room (25°C) with a 12:12 photoperiod. Freshwater crayfish have a visual range up to about 560nm (Lythgoe, 1979), therefore observations in the dark phase were achieved by using a red light (about 600nm). Observations were recorded by video recorder over a 2 hour period across the light-dark denominator once the animals had had approximately 24 hours to acclimatize to laboratory conditions. Animals were left undisturbed during the 2 hour filming period. Recordings were viewed to determine the number of times experimental animals left the refuge and the duration of this activity. Because the light cycle and video operation were on separate timing devices light and dark recording periods were not always equal. Therefore all variables examined were expressed in relation to the duration of the light or dark phase.

Four experimental conditions (3 predators and a control) were applied for each of 12 replicate trials. Potential predators were spangled perch (*Leiopotherapon unicolour*), striped gudgeon (*Gobiomorphus australis*) and water scorpion (*Lethocerus insulanus*). Gudgeon and water scorpion were found in pools with *T. glypticus* (Harding & Williamson, 2003) and water scorpion consumed *T. glypticus* in the laboratory (D. Harding, pers. obs.). Spangled perch were used as an aggressive visual predator. The same predators were used in a number of trials but prey animals were used only once (48 *T. glypticus* were used). Tank water was changed after each trial and predator treatments were randomly allocated to tanks for each replicate.

A total of 2,220 minutes were recorded for the light phase and 3,320 minutes for the dark phase comprising 550 minutes observation for each predator treatment in the light phase and 830 minutes for each treatment in the dark phase. In all treatments combined, 10 of the 48 crayfish moved from the sedge refuge a total of 15 times in the light phase (control = 2, perch = 0, gudgeon = 6, water scorpion = 7) and 28 of the 48 crayfish moved from sedge 73 times in the dark phase (control = 21, perch = 22, gudgeon = 16, water scorpion = 14). Crayfish spent 15.7 minutes away from the refuge in the light phase and 111.4 minutes in the dark phase. Overall *T. glypticus* only spent 2.3% of the total time out of the refuge.

Two-way anovas (predator treatment × light phase) were used to examine the proportion of time spent out of the refuge, and the number of times *T. glypticus* moved from the refuge (expressed as number of times per hour of observation). *T. glypticus* made significantly more moves out of the refuge in the dark phase compared to the light phase ($F_{1,88} = 9.94$, $p = 0.002$), but there was no difference detected between treatments ($F_{3,88} = 0.02$, $p = 0.995$). A higher proportion of time was also spent out of the refuge in the dark phase compared with the light phase ($F_{1,88} = 12.00$, $p = 0.001$) but there was no difference between the predator treatments ($F_{3,88} = 0.11$, $p = 0.954$). Crayfish spent from 14 to 937 seconds away from the refuge in the dark phase and from 21 to 166 seconds away from refuge in the light phase. There was no difference in the average duration of visits to the open area of the tank between predator treatments for either the light phase ($F_{2,7} = 0.96$, $p=0.430$) or the dark phase ($F_{3,24} = 0.18$, $p=0.908$).

These laboratory observations match field observations in terms of this species association with sedges, with individuals only spending a small proportion of their time away from the sedge refuge. Observations also suggest that *T. glypticus* is more active nocturnally. However, even though activity increased in the dark period, crayfish spent only a small proportion of time away from the refuge. Both nocturnal activity and the use of refuge are common behaviours in crayfish and may reduce the risk of predation (Stein & Magnuson, 1976). However, these laboratory data provide no evidence that *T. glypticus* modify their behaviour in the presence of visual or chemical cues from predators. It is possible that *T. glypticus* spend the majority of time in sedges where all resources are available, and this association has little to do with predator avoidance. Alternatively, they do use open areas more frequently in the field, but their behaviour in the laboratory was extremely modified. The strong link between *T. glypticus* and sedges would need to be confirmed in the field with night time observations of their habitat use and behaviour.

Acknowledgements

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Literature Cited

HARDING, D. & WILLIAMSON, I. 2003. A note on the habitat requirements of the swamp crayfish on Bribie Island, southeastern Queensland. Memoirs of the Queensland Museum 49(1): 452.

LYTHGOE, J.N. 1979. The ecology of vision. (Oxford University Press: New York).

RIEK, E.F. 1969. The Australian freshwater crayfish (Crustacea: Decapoda: Parastacidae), with descriptions of new species. Australian Journal of Zoology 17:101-106.

STEIN, R.A. & MAGNUSON, J.J. 1976. Behavioral response of crayfish to a fish predator. Ecology 57: 751-761.

Douglas Harding & Ian Williamson, School of Natural Resource Sciences, Queensland University of Technology, GPO Box 2434, Brisbane 4001, Australia; 12 December 2003.

A NEW GENUS AND FIRST RECORD OF CHRYSOMELINAE FROM NEW CALEDONIA (COLEOPTERA: CHRYSOMELIDAE)

C.A.M. REID AND K.I. SMITH

Reid, C.A.M. & Smith, K.I. 2004 06 30: A new genus and first record of Chrysomelinae from New Caledonia (Coleoptera: Chrysomelidae). *Memoirs of the Queensland Museum* **49**(2): 705-711. Brisbane. ISSN 0079-8835.

Zira new genus is described from New Caledonia, for *Zira nitens* sp. nov. *Zira* belongs in the Phyllocharitini and is the first member of the subfamily Chrysomelinae to be recorded from New Caledonia. The third instar larva is described. ❑ *New Caledonia, Chrysomelidae, new genus, Coleoptera.*

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The Chrysomelinae is one of the largest subfamilies of the large beetle family Chrysomelidae. It is diverse in the Southern Hemisphere on fragments of the former continental landmass Gondwana, but has not been recorded from New Caledonia (Daccordi, 1994), which is one of the smaller rafted fragments of that continent (Kroenke, 1996).

A recent collecting trip by the staff of the Queensland Museum to New Caledonia discovered a large species of Chrysomelinae high on the island's second highest mountain massif. This discovery raises the number of subfamilies in the New Caledonia island group to 9, I introduced (Bruchinae: Delobel et al., 2003) and 8 native: Cassidinae (Gressitt, 1960; Borowiec, 1999), Chrysomelinae, Criocerinae (Monrós, 1960), Cryptocephalinae (Fauvel, 1907), Eumolpinae (Lefèvre, 1885), Galerucinae (Samuelson, 1973), Lamprosomatinae (Monrós, 1956), Spilopyrinae (Reid, 2000). The new taxon belongs to the tribe Phyllocharitini, which is also the only tribe of Chrysomelinae found in New Zealand, as *Aphilon* Sharp, placed with *Phaedon* von Muelfeld in the tribe Chrysomelini (Daccordi, 1994), is a small phyllocharitine (Reid, 1995a,b). Members of the tribe Phyllocharitini occur mainly in the Southern Hemisphere and are extremely diverse in size, shape and life-history, but the New Caledonian specimens do not conform with any known genus and are therefore described as new.

In the following descriptions, larval sclerites are identified according to the nomenclatural system devised by Kimoto (1962), as used for Phyllocharitini by Reid (1991). Specimens are deposited in: Australian Museum, Sydney (AMS), Natural History Museum, Paris (MHNP), Queensland Museum, Brisbane (QMB).

Zira gen. nov.

TYPE SPECIES. *Zira nitens* sp. nov.

ETYMOLOGY. From the extinct New Caledonian language Zira or Zire (arbitrarily designated feminine) (see www.ethnologue.com/show_country.asp?name=New+Caledonia).

DESCRIPTION. *Adult. Head* (Figs 1B, 2A). Median part of frons and clypeus almost flat, with frontoclypeal suture feebly and evenly depressed and without groove or ridge from antennal base to eye; eye narrow, without emargination, placed on middle of lateral swelling of head, short posterior part of swelling (temple) contracted to parallel-sided neck; antenna situated on anterior margin of head, lower margin of head without ridge or groove between eye and mouth for retention of antenna; clypeus strongly transverse with triangular basal margin; all antennal segments elongate, of similar length and width; labrum densely setose anteriorly, with 6-9 pairs of setae; mandible with 2 apical teeth and thick but soft membranous pad near middle of inner margin; last 2 segments of maxillary palpi equal in length, apical elongate or quadrate but inner margin slightly shorter than outer, with truncate apex (slightly broader in male), penultimate segment almost triangular, first segment not grooved to receive apical segment; mentum strongly transverse, curved, with concave apical margin.

Thorax (Figs 1-2). Pronotum with single large seta in a pit (trichobothrium) on the raised margin of each angle, anterior angles rounded, hind angles slightly produced as lateral triangular teeth; pronotum transverse, broadest at base, sides evenly contracted to apex, anterior margin

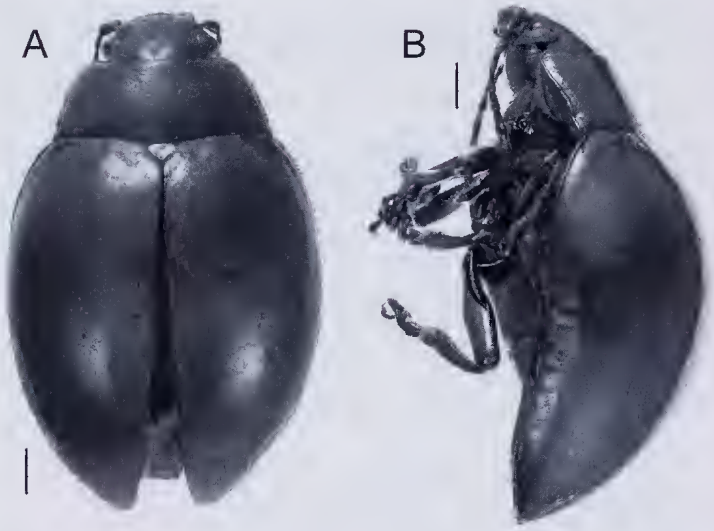

FIG. 1. *Zira nitens* Reid & Smith, adult ♂. A, dorsal (note apices of wings); B, lateral.

strongly and evenly concave; lateral and anterior margins of pronotum bordered; hypomeron without grooves or excavations; prosternum almost flat, without lateral ridges, process medially depressed and expanded at apex, about as broad as long; procoxal cavities open, hypomeral lobe short, slightly less than half width of procoxa; elytral humeri absent, elytra smoothly convex except shallow oblique basal groove towards lateral margin; epipleuron broad, at base twice width of metepisternum, entirely visible from sides, sloped at c45° from vertical, gradually attenuated to apex, without setae; anterior elytral wingbinding patch on oval swelling one third from base; median portion of mesoventrite covered by prosternal process, except concave apex of transverse lobe; wings reduced to oar-shaped unfolded strips almost as long as elytra, with single large vein; metaventrite with simple narrowly ridged margins; metendosternite with extremely short basal stalk and thin lateral arms; tibiae without ridges on external faces; first tarsal segments of male each with patch of spatulate setae, of female with simple setae and without glabrous midline; third tarsal segment not bilobed, apex truncate or shallowly concave; claws appendiculate.

Abdomen (Figs 3-4). Pygidium smooth, without median groove; sides of each ventrite bordered, margination convex; ventrites I-II fused; ventrite I with broad, truncate, intercoxal process and narrow basal border; ventrite V evenly convex, with simple medially convex (male) or truncate (female) apex; tergite VIII with distinct spiracles; sternite IX of male reduced to 2 separate struts; tegmen short and V-shaped, junction of arms weakly sclerotised; penis elongate, evenly curved in profile, smooth-walled, with small basal foramen and thin flagellum which protrudes from apex of penis in repose and includes two basal valvular structures within the endophallus; ovipositor with well-developed tergite VIII and

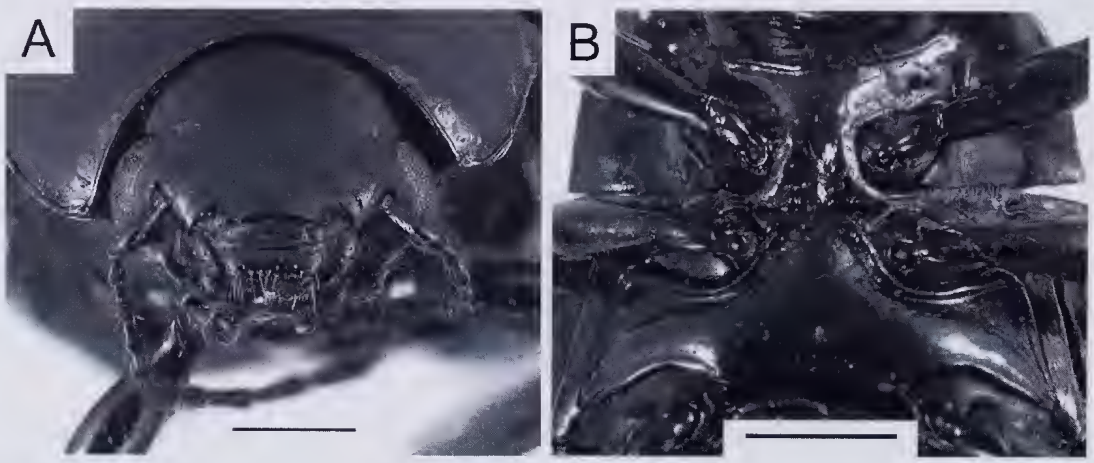

FIG. 2. *Zira nitens* Reid & Smith, adult ♂. A, head; B, venter of thorax.

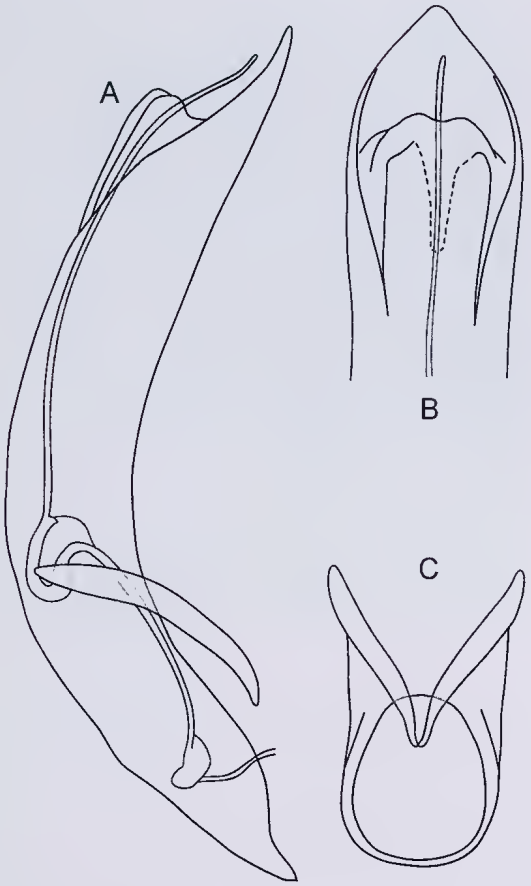

FIG. 3. *Zira nitens* Reid & Smith, adult ♂. A, aedeagus, lateral view, showing flagellum in relaxed position; B, apex of penis, dorsal view; C, tegmen and base of penis, ventral view.

sternite VIII (but without basal spiculum), simple quadrate sternite IX, pair of elongate two-segmented palpi, pair of well-developed paraprocts partly enclosing basal half of palpi and pair of irregular strip-like proctigers dorsal to these; spermatheca irregularly shaped, with well-developed basal bulb between gland and duct, latter loosely coiled, of uniform width, partly invaginated into basal bulb.

Pupa. The pupa of *Zira* is unknown.

Larva (Figs 5-6). Number of larval instars unknown. Diagnostic description of late instar larva: body form elongate, without dorsal or lateral eversible glands; all setae short (much less than than half depth of head), head setae acute, most dorsal and lateral body setae slightly clubbed; head circular, surface smooth, not microsculptured; frontal sutures attenuated, not reaching antennal cavities; 3-segmented antennae not set on prominent angular lobes; labrum deeply emarginate; mandibles palmate, third tooth largest, without prostheca; all body segments with well-defined sclerites, identified as follows: prothorax: D-DL-EP, trochantin, P, ES fused across midline, SS; mesothorax: Da (tuberculate), Dpi (tuberculate), Dpe (poorly differentiated from Dpi), DLai, DLpi, spiracle, DLe, EPa (with large protruding tubercle), EPP, trochantin, P, ES, SS; metathorax as mesothorax but without spiracle; abdomen: segments I-VI: Da (with large dorsally prominent tubercle), Dpi (with small tubercle), Dpe, DLai, DLae, DLp (large and folded), spiracle, EP (massive and posterolaterally protuberant), P, ES, SS; segment VII: all sclerites fused above laterally placed spiracles, except DLai and DLae; segment VIII: all sclerites fused above laterally placed spiracles; segment IX: spiracles absent, dorsal and lateral selerites fused forming a thick single plate, with setae on tubercles, enclosing venter and segment X; all spiracles annular; paired pseudopoda, ovoid in ventral view, with setose anterior margins, on sternites V-VIII; tarsunguli simple, without basal tooth or angular projection.

Egg. Unknown, but maturing eggs in the ovarioles were smooth and relatively large.

Biology. Host unknown, plant fragments in guts of adults and larva not identifiable. Oviparous.

Zira nitens sp. nov.
(Figs 1-6)

ETYMOLOGY. Latin *niteo*, shine; for the shining dorsal surface.

MATERIAL (all New Caledonia). HOLOTYPE: ♂ Mt Humboldt, refuge, 21°53'S 166°25'E, hand coll. 1350m, 5-8.xi.2002, Burwell, Monteith & Wright, 11136 (MHNP); PARATYPES (9): 1♂, 2♀, 1 late instar larva (in ethanol), same data as holotype (QMB); 2 ♂, 2 ♀, same data except: night collecting, 11131 (AMS, QMB); 1 ♀, Mt Ouin, 22°01'S 166°28'E, beating, 1100m, 9.xi.2002, S. Wright (QMB).

DESCRIPTION. *Size and shape*. Length: males, 9.5-10mm, females, 10-11.5mm; length to width ratio 1.6; length to height ratio: 2.6-2.7. Body ovoid in dorsal view, sides almost evenly curved from head to elytral apex; dorsum strongly convex in lateral view, but pronotum and elytra separately so, and venter convex with meta-ventrite most prominent.

Colour. Entirely dark metallic greenish-black, antennae, tarsi and margins of elytra sometimes bluish-purplish, labrum sometimes reddish-

brown, postclypeal membrane and apices of maxillary palpi yellowish-brown.

Surface sculpture. Pubescence: dorsal surfaces largely glabrous, with >6 pairs of setae on apical half of labrum, 2 pairs at apex of clypeus, 1-2 minute trichobothrial setae near inner margin of eye, trichobothrial setae at each corner of pronotum; setae increasingly dense on antennal segments, from sparse on first to dense on seventh, and uniformly dense on 8-11; venter sparsely setose, except hypomeron, sides of prosternum and metaventrite glabrous; tibiae with densely setose apices in both sexes; male with small ovoid patch of spatulate setae in middle of each first tarsomere; puncturation: upper surfaces with small, but variably sized, sparse punctures, absent from scutellum, usually inconspicuous or absent on elytra, usually stronger and denser on pronotum; a few much larger punctures at inner margin of eye, scattered along hind margin of pronotum, adjacent to upper margin of epipleuron and occasionally elsewhere; lower surfaces similar to upper but without scattered large punctures and abdominal ventrites often rugose, with obscured punctures; microsculpture: dorsal surfaces generally smooth, shining and without microsculpture, scutellum microreticulate, elytra may be faintly wrinkled or even microtuberculate at apices; ventral surfaces of thorax usually smooth, of ventrites usually finely microreticulate and often finely rugose.

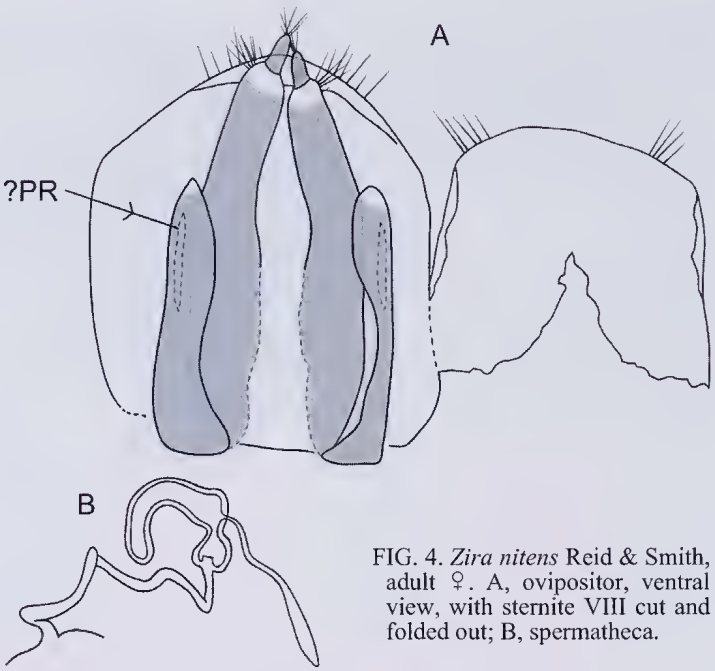

FIG. 4. *Zira nitens* Reid & Smith, adult ♀. A, ovipositor, ventral view, with sternite VIII cut and folded out; B, spermatheca.

Head. Inner margin of eye with small oval depression and/or short groove; eye narrow, without canthus, depth in lateral view 2.5-3× length; antenna about half body length, inserted on apical margin of head; second antennal segment shortest, first ovoid and 6-11 slightly more expanded than 2-5.

Thorax. Pronotum transverse, width 2-2.5× length, broadest at base, sides evenly curved towards apex; basal margin shallowly convex, apical strongly concave; anterior and sides strongly margined, base not or feebly so; pronotal surface smooth or with shallow irregular impressions near lateral margins; scutellum triangular, base slightly longer than sides; elytra strongly convex laterally and dorsally, greatest height one third from base.

Genitalia. Penis cylindrical, apex elongate triangular in dorsal view (one specimen slightly assymetric, deformed through injury?), thin and almost straight in lateral view, apical foramen elongate, with two elongate sclerites and thin flagellum emerging from endophallus; flagellum continuous through length of penis, with two basal lightly sclerotised and strongly flexed swellings; spermatheca with c-shaped apex and strong constriction between insertion points of gland and spermathecal duct, latter projecting slightly into basal bulb and short with only 2-3 coils.

Larva. Late (third?) instar: length 10mm; head width 2mm; colour: head capsule, legs and all major dorsal and lateral sclerites dark, venter pale; centres of anterior tubercles on Da pale on abdominal segments VI and VII; abdominal sclerite EP more protruding, more setose and increasingly paler (from entirely dark on segment I to entirely pale on VIII) from base to apex of abdomen, sclerite P pale on abdomen; setae pale; larger setae : all head setae acute, not on tubercles, longest <0.2 head depth, vertex with single row of 5 near midline, and 7 around stemmata, frons with pair at base and 4 pairs at apical margin, clypeus with 4 pairs; pronotal shield with anterior row of c10 short clubbed

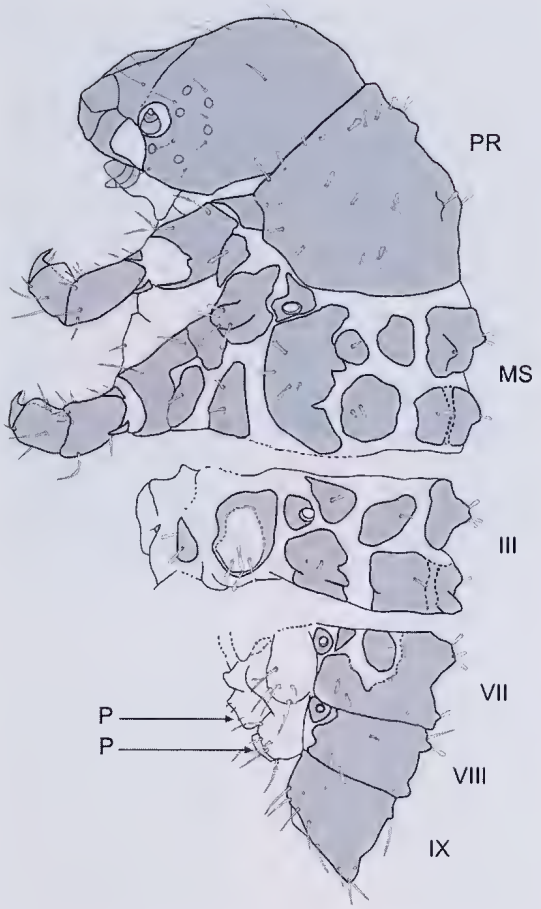

FIG. 5. *Zira nitens* Reid & Smith, late-instar larva. A, lateral, with metathorax, abdominal segments I-II and IV-VI omitted.

setae and several similar scattered behind; other dorsal and lateral thoracic and abdominal sclerites with short clubbed setae (as illustrated), the longest in a cluster at the apex of the protruding lateral EP sclerite, setae longer and mostly acute on segments VIII & IX; stemmata in 4+2 formation; leg setae acute, longest on dorsal part of tibiotarsus (as long as this segment); third segment of antenna slightly elongate, sensorium at apex of second segment almost flat; tarsungulus short, length half width, and strongly hooked, without angulate base.

DISTRIBUTION AND BIOLOGY. New Caledonia is 500km long with a highly dissected central mountain chain running its full length. Most specimens of *Zira nitens* were collected at 1,350m about 2km west of the 1,618m summit of

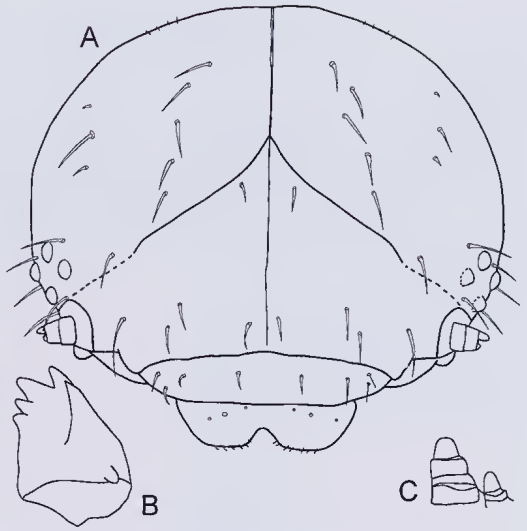

FIG. 6. *Zira nitens* Reid & Smith, late-instar larva. A, head anterior; B, left mandible, internal view; C, maxillary and labial palpi.

Mt Humboldt. This is the second highest mountain on the island and dominates the southern portion of the mountain chain about 40 km north of the capital, Nouméa. Mt Humboldt is a major relictual focus of the island with many plants endemic to its summit zone (Lowry, 1998). One additional *Zira* specimen came from 1,100m just below the summit of Mt Ouin, which is an outlier of the Humboldt massif and 15km to its south. The Humboldt specimens were all collected on the ground while headlight collecting at night in an area of stunted montane heath traversed by a path from the Humboldt helipad to the "Forêt des Mousses" (Fig. 7). Vegetation was up to a metre in height and included *Dracophyllum* (Epacridaceae), pygmy bamboo (*Greslania*, Poaceae), *Gahnia* (Cyperaceae) and ferns interspersed with patches of bare, gravelly soil. No plant association for the beetles was noted. Two other flightless black beetles, of similar size to *Zira nitens*, were active on the ground at the same time — one a eumolpine chrysomelid (*Taophila* Heller) and the other an unidentified melolonthine scarab. The single Mt Ouin specimen was taken beating low vegetation along a roadside adjacent to rather similar, but less exposed, vegetation.

PHYLOGENY AND BIOGEOGRAPHY. The adult of *Zira* is most similar to larger members of the New Zealand Phyllocharitini, *Allocharis* Sharp, *Cyrtonogetus* Broun and *Eualema* Broun,

FIG. 7. Habitat of *Zira nitens* at Mount Humboldt. (photo: Susan Wright)

with which it shares the following attributes: eyes on lateral swellings; frontoclypeus without deep grooves; at least female maxillary palpi not apically expanded; pronotum with trichobothrial setae in each corner, without irregular deep depressions at sides; pronotum with lateral and anterior borders but without obvious basal border; prosternum not anteriorly or posteriorly raised; elytra not striate, at least on disc; pads of spatulate setae on all male basal tarsi; third tarsal segment not bilobed; penis elongate, with small basal foramen; ovipositor with two segmented vaginal palp; larva without extrusible glands, with conical pre-apical ventral ampullae. Most of these similarities appear to be plesiomorphies for Phyllocharitini and the group of genera is therefore weakly defined. *Zira* most obviously differs from these genera by much greater body convexity, pronotal shape (broadest at base) and broadly open procoxal cavities (in *Cyrtonogetus crassus* Broun the procoxal cavities are open, but only narrowly so). The Australian genus *Strumatophyma* Baly is similar to *Zira*, with widely open procoxal cavities and non-striate elytra, but it has strongly grooved frontal sutures, pronotum broadest anteriorly and laterally depressed, tuberculate elytra, simple claws and a deep depression on the apical ventrite of both sexes.

The larvae of the New Zealand genera are undescribed, but the habitus of a late instar larva of *Allocharis* has been sketched (Reid, 1995a) and larvae of three genera of Australasian Phyllocharitini have been described (Kimoto, 1962; Reid, 1991). The larva of *Zira* is essentially similar to all of these, especially in having a dorsally placed pair of frontal setae, laterally tuberculate sclerites and at least 3 pairs of prolegs, but differs by setal structure, number of rows of tubercles, or sclerotisation of abdominal apex.

Determination of *Zira*'s relationships will require a phylogenetic revision of the whole tribe, but the available evidence is that *Zira* belongs to a group of genera previously only known from New Zealand.

The presence of an unusual flightless and relatively plesiomorphic member of Phyllocharitini on a rafted fragment of Gondwana strengthens the argument that this tribe is ancient. Daccordi (1994, 1996) noted relationships between phyllocharitine genera in South America, New Zealand and Australia, although nonphyllocharitine genera were included in his discussion (Reid, 1995b). Other remnant Gondwanan chrysomelids on New Caledonia include a genus of Spilopyrinae (Reid, 2000) and possibly the Lamprosomatinae (Monrós, 1956).

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LITERATURE CITED

BOROWIEC, L. 1999. A world catalogue of the Cassidinae (Coleoptera: Chrysomelidae). (Biologica Silesiae: Wroclaw).

DACCORDI, M. 1994. Notes for phylogenetic study of Chrysomelinae, with descriptions of new taxa and a list of all the known genera (Coleoptera: Chrysomelidae, Chrysomelinae). Pp. 60-84. In Furth, D.G. (ed.) Proceedings of the Third International Symposium on the Chrysomelidae, Beijing, 1992. (Backhuys: Leiden).

1996. Notes on the distribution of the Chrysomelinae and their possible origin. Pp. 399-412. In Jolivet, P.H.A. & Cox, M.L. (eds) Chrysomelidae biology, vol. 1: the classification, phylogeny and genetics. (SPB Academic Publishing: Amsterdam).

DELOBEL, A., SEMBÈNE, M., FÉDIÈRE, G. & ROGUET, D. 2003. Identity of the groundnut and tamarind seed-beetles (Coleoptera: Bruchidae: Pachymerinae), with the restoration of *Caryedon gonagra* (F.). Annales de la Société Entomologique de France 39(3): 197-206.

FAUVEL, A.1907. Faune analytique des Coléoptères de la Nouvelle-Caledonie. Revue d'Entomologie 26: 149-152.

GRESSITT, J.L. 1960. Papuan, west-Polynesian hispine beetles (Chrysomelidae). Pacific Insects 2(1): 1-90.

KIMOTO, S. 1962. Descriptions of immature stages of Japanese Chrysomelinae belonging to the generic groups *Chrysolina*, *Gonioctena*, *Potatinia*, *Phola* and *Phaedon* (Coleoptera). Journal of the Faculty of Agriculture, Kyushu University 12(2): 89-102.

KROENKE, L.W. 1996. Plate tectonic development of the western and southwestern Pacific: Mesozoic to the present. Pp. 19-34. In Keast, A. & Miller, S.E. (eds) The origin and evolution of Pacific Ocean biotas, New Guinea to Eastern Polynesia: patterns and processes. (SPB Academic Publishing: Amsterdam).

LEFÈVRE, E. 1885. Eumolpidarum hucusque cognitarum catalogus, sectionum conspectu systematico, generum sicut et specierum nonnullarum novarum descriptionibus adjunctis. Mémoires de la Société Royale des Sciences de Liège (2)11: 3-172.

LOWRY, P.P. 1998. Diversity, endemism, and extinction in the flora of New Caledonia. Pp. 181-206. In Peng, C-I. & Lowry, P.P. (eds) Proceedings of the International Symposium on rare, threatened and endangered floras of Asia and the Pacific. (Academica Sinica: Taiwan).

MONRÓS, F. 1956. Revision generica de Lamprosominae con descripcion de algunos generos y especies nuevas (Col., Chrysomelidae). Revista Agronómica del Noroeste Argentino 2(1): 25-77.

1960. Los géneros de Chrysomelidae (Coleoptera). Opera Lillioana 3: 5-337.

REID, C.A.M. 1991. Immature stages of the genera *Johannica* Blackburn, *Lamprolina* Baly and *Chalcolampra* Blanchard (Coleoptera, Chrysomelidae, Chrysomelinae). Journal of Natural History 25: 341-357.

1995a. A cladistic analysis of subfamilial relationships in the Chrysomelidae sensu lato (Chrysomeloidea). Pp. 559-631. In Pakaluk, J. & Slipinski, S.A. (eds) Biology, phylogeny and classification of Coleoptera. Papers celebrating the 80th birthday of Roy A. Crowson. (Muzcum i Instytut Zoologii PAN: Warszawa).

1995b. Book review: Proceedings of the third international symposium on the Chrysomelidae. Furth, D. (ed.) 1994. Backhuys publishers, Leiden. Novel aspects of the biology of Chrysomelidae. Jolivet, P., Cox, M. L. & Petitpierre, E. (eds), 1994, Kluwer, Dordrecht. Journal of the Australian Entomological Society 34: 224, 228.

2000. Spilopyrinae Chapuis: a new subfamily in the Chrysomelidae and its systematic placement (Coleoptera). Invertebrate Taxonomy 14: 837-862.

SAMUELSON, G.A. 1973. Alticinae of Oceania (Coleoptera: Chrysomelidae). Pacific Insects Monograph 30: 1-165.

CONTINUED INCREASE IN EAST AUSTRALIAN HUMPBACK WHALES IN 2001, 2002. *Memoirs of the Queensland Museum 49(2): 712. 2004:-* Observations of humpback whales passing Point Lookout (27°26'S, 153°33'E) on North Stradbroke Island between 1984 and 1999 have shown that there has been a steady increase in the east Australian proportion of the Area V (130°E – 170°W) stock over that period (Paterson et al., 2001). This note describes the results of observations in 2001 and 2002 which show continued increase in stock size.

Observations were made by RP and PP from the same 65m high position as before, for the 10 weeks encompassing the peak of the northern migration. Methods of observation and analysis followed those described by Paterson et al. (1994, 2001). A total of 1,093 of northbound humpback whales were seen in 2001 and 984 in 2002. On 28 June 2002, 84 humpback whales were seen in 10.8 hours, the largest number in a single day since observations began in 1978.

The timings of the migrations past Point Lookout are shown on a weekly basis in Fig. 1. The differences between 2001 and 2002 are typical of the variation seen between migrations in previous years (Paterson et al., 1994, 2001).

Figure 2 shows the number of humpback whales seen per 10h averaged over the four and eight weeks at the peak of the migrations from 1984 – 2002. The vertical scale is logarithmic so that a constant rate of increase appears as a straight line. Linear regression lines, calculated using the logarithm of the values, give the average annual rates of increase shown in Table 1. The results show that a constant rate of increase is a good fit to the data points.

The rates of increase are within the confidence intervals for previous estimates (Paterson et al., 1994, 2001). From the stock size estimate for 1999 of 3,600 ± 440 whales (Paterson et al., 2001), it is estimated that the stock size in 2002 would have been 4,860 for 10.5% increase or 4,900 for 10.8% increase (Table 1).

TABLE 1. Estimates of annual rate of increase and confidence intervals from data observed over four and eight weeks at the peak of the northern migration.

	4 weeks	8 weeks
Number of points	15	11
Rate of increase	10.8%	10.5%
95% confidence interv.	10.2 - 11.5%	10.0 - 11.1%
99% confidence interv.	9.9 - 11.8%	9.7 - 11.4%
Correlation coefficient	0.996	0.998

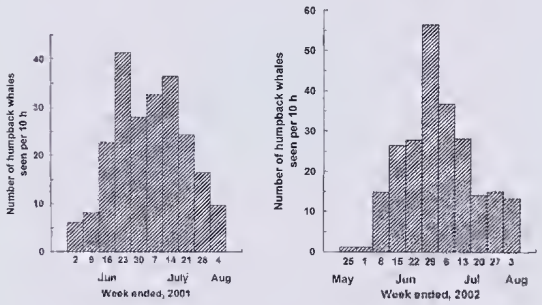

FIG. 1. Humpback whale sightings on a weekly basis observed from Point Lookout.

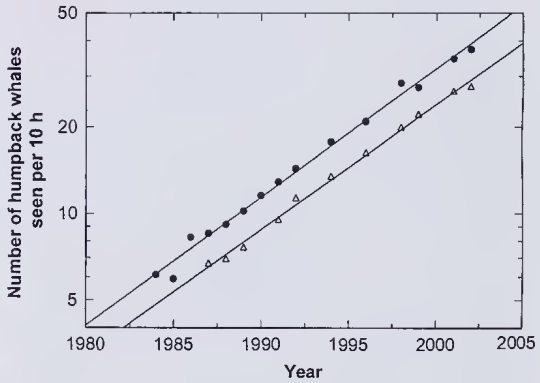

FIG. 2. Humpback whale sightings per 10h averaged over the four weeks (filled circles) and eight weeks (open triangles) of the northern migration.

Literature Cited

PATERSON, R., PATERSON, P. & CATO, D.H. 1994. The status of humpback whales *Megaptera novaeangliae* in East Australia thirty years after whaling. Biological Conservation 70, 135-142.

2001. The status of humpback whales *Megaptera novaeangliae* in East Australia at the end of the 20th Century. Memoirs of the Queensland Museum 46(2): 579-586.

Robert Paterson, Patricia Paterson, PO Box 397, Indooroopilly 4068, and Douglas H. Cato, Defence Science & Technology Organisation, PO Box 44, Pyrmont 2009, Australia, 10 June 2003.

REDESCRIPTION OF *WOOLUNGASAURUS GLENDOWERENSIS* (PLESIOSAURIA: ELASMOSAURIDAE) FROM THE LOWER CRETACEOUS OF NORTHEAST QUEENSLAND

SVEN SACHS

Sachs, S. 2004 06 30: Resdescription of *Woolungasaurus glendowerensis* (Plesiosauria: Elasmosauridae) from the Lower Cretaceous of Northeast Queensland. *Memoirs of the Queensland Museum* **49**(2): 713-731. Brisbane. ISSN 0079-8835.

Woolungasaurus glendowerensis Persson, 1960, was based on an incomplete postcranial skeleton, comprising cervical, pectoral, dorsal and caudal vertebrae, an almost complete sacrum, as well as elements of the pectoral and pelvic girdles and of the fore and hind paddles. Following comparisons with specimens referable to all valid genera of the Elasmosauridae, this specimen and additional material is identified as belonging to *Styxosaurus*. It is the earliest record of this genus and the first in the Southern Hemisphere. ❑ *Plesiosauria, Elasmosauridae, Woolungasaurus, Styxosaurus, Lower Cretaceous, northeast Queensland.*

Sven Sachs, Institut für Paläontologie, Freie Universität Berlin, Malteser Strasse 74-100, Haus D, 12249 Berlin, Germany; 19 November 2001.

The Elasmosauridae are a well-known family within the Plesiosauroidea. Most skeletal remains are known from the Northern Hemisphere (especially North America, Carpenter, 1999). In Australasia, only few localities have yielded their remains (Cruickshank et al., 1999). An almost complete, but badly crushed skull from the Aptian of northeast Queensland is a new species of *Tuarangisaurus*. In about the same region as the skull, Glendower Station near Prairie, postcranial skeletal remains were discovered by A.W. Fergusen at his landholdings in 1891 (QMF3567) and 1893 (QMF3568). This specimen was described by Persson (1960) as a new genus and species, *Woolungasaurus glendowerensis*. Persson not always adequately described the remains and also misidentified some elements. His diagnosis is based on weak characters of the vertebrae, the coracoid and the propodials. For these reasons Welles (1962) considered the genus a *nomen dubium*.

The purpose of this paper is to redescribe and classify the postcranial material referred to *Woolungasaurus glendowerensis*. The type material and other referred specimens are housed in the Queensland Museum (QM). Besides a postcranial skeleton is described, which is on display at the Richmond Marine Fossil Museum, Richmond. It is more complete than the type and can be referred to the same taxon, as all elements preserved in both specimens are identical (Tables 1, 2).

In the comparison, all elasmosaur genera (revised by Carpenter, 1999 and Storrs, 1999) have been considered, except for the doubtful taxa, *Fresnosaurus* Welles, 1943, *Moraenosaurus* Welles, 1943 and *Aphrosaurus* Welles, 1943.

INSTITUTIONAL ABBREVIATIONS. AMNH, American Museum of Natural History, New York, USA; ANSP, Academy of Natural Sciences, Philadelphia, USA; DMNH, Denver Museum of Natural Sciences, Denver, USA; QM, Queensland Museum, Brisbane, Australia; RMF, Richmond Marine Fossil Museum, Richmond, Australia; SDSM, South Dakota School of Mines, Rapid City, USA.

SYSTEMATIC PALAEONTOLOGY

SAUROPTERYGIA Owen, 1860
PLESIOSAURIA De Blainville, 1835
PLESIOSAUROIDEA Nopcsa, 1928
ELASMOSAURIDAE Cope, 1868
Styxosaurus Welles, 1943

TYPE SPECIES. *Styxosaurus* (*Cimoliosaurus*) *snowii* Williston, 1890.

DIAGNOSIS. See Carpenter (1999:158).

Styxosaurus glendowerensis comb. nov.

Woolungasaurus glendowerensis: Persson, 1960: 11-16.
Woolungasaurus glendowerensis: Welles, 1962: 47-48 (nomen dubium).
Woolungasaurus glendowerensis: Persson, 1963: 22.
Woolungasaurus glendowerensis: Persson, 1982: 649-650.
Woolungasaurus glendowerensis: Kear, 2003: 288-289 (nomen dubium, sensu Welles, 1962).

MATERIAL. Holotype: QMF3567. Incomplete skeleton (Fig. 1A) comprising 24 cervical vertebrae (including the axis); 3 pectoral vertebrae; 9 dorsal vertebrae; 3 sacral

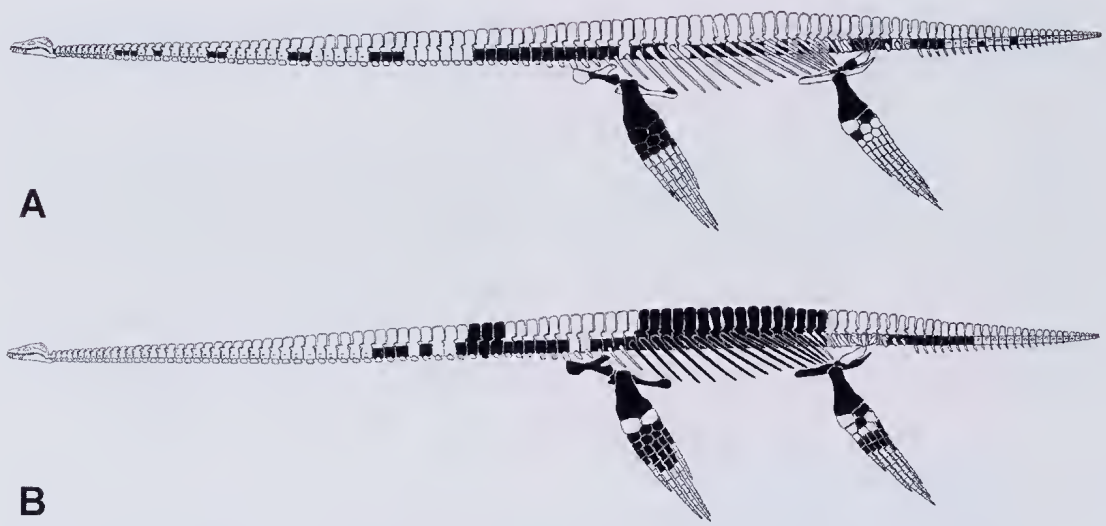

FIG. 1. Outline drawings of the skeletons of *Hydrotherosaurus* (after Welles, 1943), showing the elements present in QMF3567 (A) and RMF R271 (B). Rib-fragments are not included in (A) because of their unclear positions.

vertebrae; 7 caudal vertebrae; 2 partial scapulae; partial coracoids; right humerus; 1 ulna; 1 radius; 9 carpals, including 1 intermedium; 2 phalanges; both femora; the left ?fibula; 1 tarsal; 2 ?metacarpals; 1 phalange; a partial ?pubis; a partial ?ilium; a partial ?ischium; and unidentifiable girdle elements. From Glendower Station, near Prairie, Flinders Shire, North Queensland. Horizon: Wallumbilla Formation, Doncaster Member (Late Aptian, Lower Cretaceous; Day, 1969) (Fig. 2).

REFERRED SPECIMENS. RMF R271, an incomplete skeleton (Fig. 1B) comprising 15 cervical vertebrae, 3 pectoral vertebrae, 17 dorsal vertebrae, 10 caudal vertebrae, both scapulae, coracoids, clavicles and humeri, 1 manual intermedium , 1 radiale, metacarpals I-III; both ischia, pubes, femora, 1 ?fibula, 1 tarsal ?intermedium and 26 phalanges. From Grampian Valley, Richmond Shire, North Queensland, Wallumbilla Formation, Doncaster Member, Late Aptian, Lower Cretaceous (Day, 1969) (Fig. 2).

QMF3568, incomplete left humerus. Locality: No locality data were associate with the specimen, but it most probably belongs to holotype.

QMF2634, anterior portions of both coracoids and two dorsal vertebrae. From Claypan Ridge near Rainscourt Station, Richmond Shire, Queensland. Horizon: Wallumbilla Formation, Doncaster Member (Late Aptian, Lower Cretaceous; Day, 1969) (Fig. 2).

DIAGNOSIS. Small elasmosaurid circa 5m long; axis centrum longer than wide or high; lateral longitudinal crest in cervical vertebrae absent from posterior of mid-cervical region; three pectoral vertebrae; sacral ribs I and II robust compared with sacral rib III; sacral rib I oriented posteriorly at an angle of about 35°, sacral rib II oriented posteriorly at an angle of about 30°; sacral rib III slender compared with sacral ribs I and II and straight; anterior portion of coracoid with prominent transverse keel medially on ventral side; intercoracoidal foramen prominent, heart-shaped; coracoid blade longer than anterior coracoid portion; scapula anteroposteriorly long and dorsoventrally slender; scapula shaft slightly concave medially; prominent ridge separating ventral shaft from dorsal process of scapula; dorsal process posteriorly directed at 60° to horizontal plane; clavicles slender, posteriorly curved at 45° to horizontal plane; clavicula suture straight, forming distinct sagittal vault ventrally; humerus more prominent than femur; ulna and radius almost quadratic; femora more slender than humeri; fibula pentagonal; foramen obturatum broad oval; pubic symphysis straight; posterior edge of pubis, forming border of foramen obturatum, wide and slightly concave; ischium slender in relation to pubis; anterior edge of ischium wide and slightly concave.

DESCRIPTION. *Vertebrae.* QMF3567 includes 47 vertebrae, comprising 24 cervicals, 3 pectoral, 9 dorsals, 3 sacrals and 7 caudals (including a caudosacral vertebra) (Table 1). Only 9 are preserved in association with parts of the neural arches. There are a number of isolated neural arches and neural spines. Persson (1960: 12) stated that all neural arches are fused with the centrum without a visible suture; however, there are sutures visible on two of the dorsal vertebrae, which still bear parts of the neural arches. Also, in

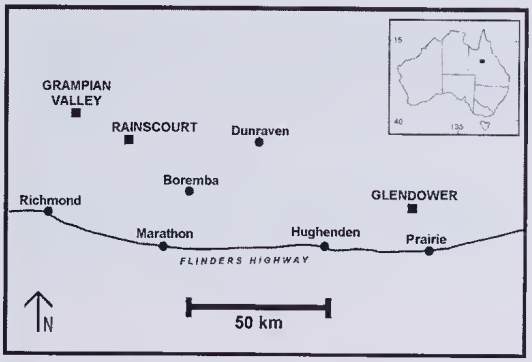

FIG. 2. Map of the Richmond – Hughenden area in north Queensland showing the localities of QMF3567 at Glendower, QMF2634 at Rainscourt and RMF R271 at Grampian.

all cervical vertebrae, the neural arches are broken at the same level, suggesting that they were not fused with the centra. This, at least, suggests that QMF3567 represents a juvenile or sub-adult individual.

Axis. QMF3567. Most of the centrum of the axis except for its dorsal surface is preserved (Fig. 3A-C). It is anteroposteriorly elongated, clearly longer than wide or high giving it a rectangular outline in lateral view. The ventral surface is concave and bears a sharp sagittal crest that originates from the edge of the anterior articular facet and terminates at the edge of the posterior one. In the middle of the crest two barely visible nutritive foramina are present. On both sides of the sagittal crest the ventral surface is slightly depressed. The rib facets are prominent, broad oval in outline and are situated laterally in about the middle of the centrum. The anterior and posterior articular facets of the centrum are incomplete, in which the dorsal edges are missing. When complete they probably had a nearly circular outline. Both articular facets are weakly concave and surrounded by thickened edges, of which the ventral sides are bulged. The dorsal side of the centrum is planar, as the entire dorsal section of the vertebra is missing. In the centre of the dorsal side, two long-oval foramina are situated.

The size and the shape of this vertebra suggest that it represents the axis. Most described elasmosaurs with preserved anteriormost cervicals are adult individuals. In this stage the axis is coossified with the atlas and forms the atlas-axis complex (Carpenter, 1999). Only in juvenile individuals can the axis be found as an isolated element.

Remarks. Usually in elasmosaurs, as in *Occitanosaurus* (Bardet et al., 1999), *Muraenosaurus* (Andrews, 1910), *Brancasaurus* (Wegner, 1914), *Libonectes* (Welles, 1949), *Hydrotherosaurus* (Welles, 1943), *Aristonectes* (Gasparini et al., 2003) and *Tuarangisaurus* (Wiffen & Moisley, 1986) the axis is antcroposteriorly short and high. This feature is found in most plesiomorphic sauropterygians. Only the advanced elasmosaurs *Styxosaurus* (Welles & Bump, 1949; Carpenter, 1999), *Hydralmosaurus* (Cope, 1877, Welles, 1952) and *Elasmosaurus* (Cope, 1869; Welles, 1952) have an axis that is long and low.

Cervical Vertebrae. QMF3567. The next anteriormost of the preserved cervical vertebrae (Fig. 3D-F) is clearly larger than the axis and may, after its size and proportion, have come from the middle of the anterior section of the neck (based on comparisons with the cervical vertebrae of *Styxosaurus snowii*, after Welles & Bump, 1949: table 2). The remaining anterior cervical vertebrae have a rectangular centrum that is longer than wide or high. In about the mid-section of the neck, the shape of the vertebrae becomes more quadratic in dorsal view, in which the centra are clearly wider than long.

All cervical centra bear a pair of long-oval nutritive foramina in the centre of their ventral surface. These foramina are separated by a ridge that is thinnest in the anterior vertebrae and becomes broader and flatter in the posterior cervicals. Lateral of the ridge, the ventral surface is longitudinally excavated. This depression is deepest in the anterior cervical vertebrae. The rib facets are very prominent. They are situated about in the middle of the lateroventral surface in the anterior vertebrae, where they are anteroposteriorly expanded. Beginning in about the mid-cervicals, the rib facets begin to shift dorsally so that by the most posterior cervicals they are situated in the centre of the lateral surface. Here, their articular facets have a high oval outline and are expanded laterally. Anteriorly and posteriorly of the articular facets the lateral surface is concave.

The centra of the anterior cervical vertebrae bear a sharp horizontal crest in the middle of the lateral surface.Iit was differently named (Brown, 1981: 330), and is here called 'lateral longitudinal crest', following Welles (1943) and Persson (1963). Dorsal and ventral to the crest, the surface of the centrum is concave. The lateral longitudinal crest is absent after approximately the mid-cervical region. The anterior and posterior articular facets of the centra are broad oval in

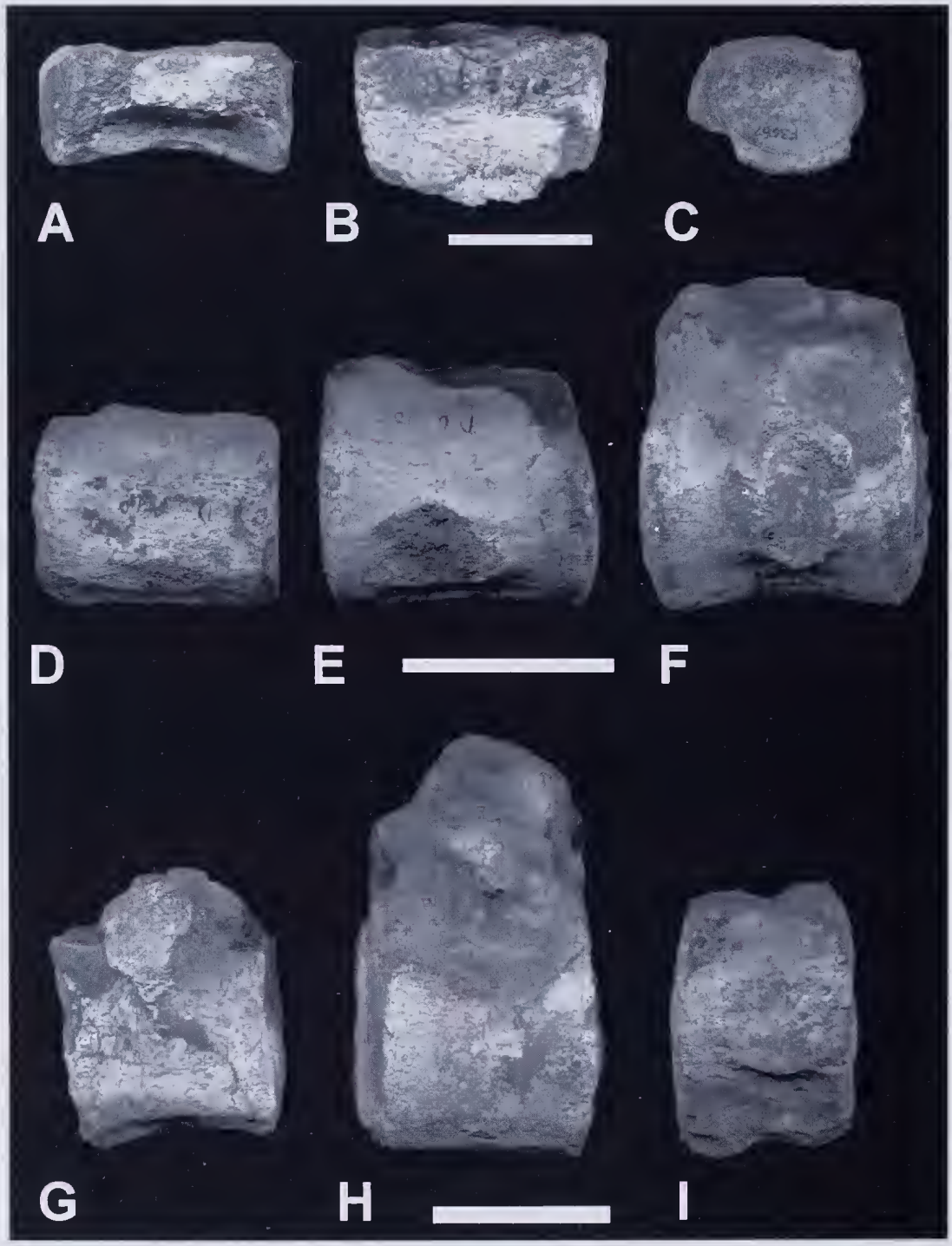

FIG. 3. A-C, QMF3567; axis centrum in lateral (A), ventral (B) and posterior (C) views. Scale = 2 cm. D-F, QMF3567; lateral views of an anterior (D), mid (E) and posterior (F) cervical vertebra. G, QMF3567; pectoral vertebra in lateral view. H, QMF3567; dorsal vertebra in lateral view. I, QMF3567; caudal vertebra in lateral view. Scales = 5cm.

shape and weakly concave. Conspicuously these facets are wider in the anterior- and posteriormost vertebrae, while they are nearly circular in the mid-cervicals. The neural canal is moderately deepened, so that the dorsal surface of the anterior and posterior articular surfaces is just slightly concave. The edge of the articular facets is relatively thin; their ventral surface lacks a notch.

RMF R271. The 15 cervical vertebrae preserved in the Richmond specimen are from the mid- and posterior section of the neck (Table 1). They resemble in shape the cervical vertebrae of QMF3567 and shall therefore not be described.

Remarks. Most elasmosaurs possess a number of slightly variable synapomorphies in the cervical vertebrae. In general, at least in adult or subadult elasmosaurs, a pair of nutritive foramina is present in about the middle of the ventral surface, separated by a sagittal keel. Also a lateral longitudinal crest is developed in the anterior cervicals, mostly reaching back to the mid-cervical level, but sometimes also into the posterior region of the neck (e.g. in *Microcleidus* (Owen, 1865), *Thalassomedon* (Welles, 1943), *Hydralmosaurus* (Cope, 1877) or *Callawayasaurus* (Welles, 1962)). Brown (1981) discussed the significance of the lateral longitudinal crest and mentioned that it is sometimes missing in juveniles (e.g. in *Muraenosaurus*) and is only fully developed in adult elasmosaurs. Its position in the vertebrae (in the mid-, dorsal or ventral section of the lateral centrum) is highly variable and therefore of no phylogenetic relevance. However, the presence of a lateral longitudinal crest in QMF3567 indicates that already in some long-necked juveniles a well developed crest was present. Also the presence is not limited to the Elasmosauridae, as a similar crest has been found in the plesiosaurids *Plesiosaurus brachypterygius* and *P. guilelmiimperatoris* (Bardet et al, 1999; Fraas, 1910). The shape of the vertebrae, which is either quadratic or rectangular in lateral view can be considered as phylogenetically significant (Brown, 1981). The general shape of the cervicals is similar to that of *Microcleidus* (Owen, 1865, pl. 5), *Styxosaurus* (Welles & Bump, 1949: pl. 85) *Terminonatator* (Sato, 2003: fig. 9) and *Elasmosaurus* (Cope, 1869: pl. 2, fig. 5 & pl. 3).

Pectoral and Dorsal Vertebra. QMF3567. Three pectoral vertebrae and 9 dorsal vertebrae are preserved (Fig. 3G-H). In the pectoral and anterior dorsal vertebrae, the centra are wider than long so that their articular facets have a broad oval outline. In the mid-dorsals the articular facets become more circular and the centra have a nearly quadratic outline in lateral view. The pectoral vertebrae bear prominent transversal processes with high oval rib facets as visible in lateral view. The latter are situated in the middle of the posterior section of the centrum. In the pectoral vertebrae the transverse processes come out of centrum, in the anterior dorsal vertebrae they are situated lateral to the neural arches. In these vertebrae the transversal processes are slightly oriented posterodorsally in lateral view, with the rib facets more triangular in cross-section. On one of the better preserved anterior dorsal vertebra, parts of the prezygapophyses as well as the ventral portion of the neural spine are preserved. The latter is also somewhat oriented posteriorly with an angle of about 20° to the vertical in lateral aspect. The anterior and posterior articular facets of this vertebra are nearly circular and weakly concave, with sharp borders. Ventrally, the nutritive foramina are situated in the middle of the centrum and are well separated by a broad, shallow, anteroposteriorly running ridge.

RMF R271. Three pectoral and 17 dorsal vertebrae are present in the Richmond specimen, representing the entire, or almost the entire, midsection of the skeleton (total number of pectorals/dorsals in *Styxosaurus snowii* 22, after Welles & Bump, 1949) (Table 1). Some dorsal vertebrae are complete and well preserved. The neural arches are short and robust; the neural spines are about 1.5 × as high as the centrum. In their general appearance the dorsal vertebrae of RMF R271 resemble those of QMF3567 and shall therefore not be described in more detail.

Remarks. According to Brown 1981 (sensu Seeley, 1874) pectoral vertebrae are transitional between cervicals and dorsals, in which the rib articulates with the centrum and the neural arch. Three pectoral vertebrae are present in *Occitanosaurus* (Bardet et al,. 1999), *Muraenosaurus* (Andrews, 1910), *Brancasaurus* (Wegner, 1914), *Styxosaurus* (Welles & Bump, 1949), *Thalassomedon* (Welles, 1943) and *Hydralmosaurus* (Welles, 1952). In *Callawayasaurus* (Welles, 1962) and *Hydrotherosaurus* (Welles, 1943) there are two. Wider than long centra are considered synapomorphies of the elasmosaurids. No other characteristic features could be taken from the pectoral and dorsal vertebrae.

Sacral Vertebrae. QMF3567. Three articulated sacral vertebrae are preserved (Fig. 4). On the right side (as well as on the left side in the first vertebra), the sacral ribs are connected with the

centra. The centra are wider than long and high and somewhat higher than long. The articular facets of the centra have relatively sharp edges and are slightly concave. On the ventral surface of the centra nutritive foramina are absent. In the caudosacral vertebra three small foramina are present in the middle of the ventral surface. The neural spines are not preserved and the zygapophyses are only barely visible in the first and second vertebra, while they are missing in the third. The neural canal is filled with sediment in the first and second vertebra and is well exposed in the third sacral vertebra. Here it can be seen that the neural canal was very broad, occupying more than half of the dorsal surface of the centrum, whereas it seems to be smaller in the first sacral vertebra. The right sacral ribs are completely preserved as well as partially the left one of sacral vertebra I. All sacral ribs are about equal in length and connect the vertebrae in the dorsal half of their lateral midsection, but they also touch the ventral section of the neural arches. The first and the second rib widens laterally, while the third sacral rib is, compared to them, more slender. In dorsal view, the first sacral rib is posteriorly directed at about 35°, the second at about 30°. The third sacral rib is almost straight laterally oriented. In the caudosacral vertebra only the articular surface for the sacral ribs is preserved. These are situated dorsally in the lateral midsection, but reach not up to the neural arches.

FIG. 4. Sacral vertebrae of QMF3567 in dorsal view. Scale = 5cm.

Remarks. It is unclear if the total number of sacral vertebrae is three or if the considered caudosacral vertebrae represents the fourth sacral vertebra. Usually four sacral vertebrae are present in elasmosaurids such as *Occitanosaurus* (Bardet et al., 1999), *Muraenosaurus* (Andrews, 1910), *Terminonatator* (Sato, 2003), *Styxosaurus* (Welles & Bump, 1949), *Elasmosaurus* (ANSP 10081, pers. obs. 2001) and *Hydralmosaurus* (Welles, 1952). The number is 3 in *Brancasaurus* (Wegner, 1914), *Thalassomedon* (Welles, 1943) and *Hydrotherosaurus* (Welles, 1943). A more detailed comparison was not possible, as only of *Muraenosaurus* (Andrews, 1910: fig. 56) and *Brancasaurus* (Wegner, 1914: figs 5, 6) good descriptions and figures of the sacral ribs have been published.

Caudal Vertebrae. QMF3567. Seven caudal vertebrae, including a caudosacral vertebra (see sacral vertebrae), are preserved (Fig. 3I). The centra are robust and wider than high and long and higher than long. The articular facets of the centra are slightly concave and surrounded by thickened edges. The surfaces for the articulation of the haemapophyses are situated in the ventral mid-section of the centrum and have a nearly triangular outline. A broad, shallow excavation separates the surfaces on each side. Between the anterior and posterior articular facet of the centrum there is a sharp crest. In the centre of the ventral surface the nutritive foramina are present, which are relatively small and well separated. The rib facets are prominent, circular in outline and are situated in the middle of the lateral surface of the centrum. The shape of the vertebrae becomes more circular posteriorly, so that the proposed mid-caudal vertebra has a nearly circular articular facet in anterior view. In this specimen, the rib facets are very prominent

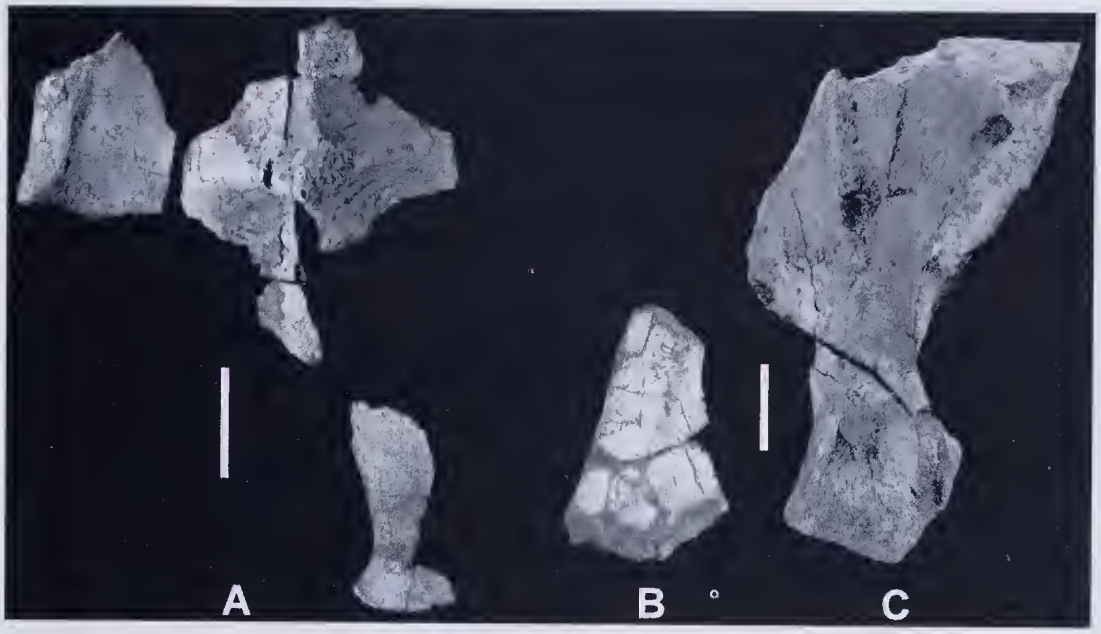

FIG. 5. A, QMF3567; coracoid fragments. Scale = 10cm. B, QMF3567; posterior section of the right scapula. C, RMF R271; right scapula. Scale = 5cm. All in ventral view.

and occupy almost the entire mid-lateral surface of the centrum.

RMF R271. Ten anterior caudals are present in the Richmond specimen (Table 1), which resemble in shape those of QMF3567 and shall therefore not be described.

Remarks. The general shape of the preserved caudal vertebrae corresponds well with that in *Styxosaurus snowii* (Welles & Bump, 1949: pl. 85), but the shape of the caudal vertebrae within the Elasmosauridae is not very informative taxonomically.

Ribs. QMF3567. Although numerous rib-fragments are presented in the holotype material, no complete ribs (except of the sacral ribs) could be assembled. In general, these fragments seem to belong to the dorsal ribs. They are single-headed and have a broad oval articulation surface that is slightly concave and somewhat oriented medially.

RMF R271. In the Richmond specimen a number of ribs and rib fragments are present. Among them there are some complete ribs, which show the for clasmosaurs typical appearance in having an oval cross section in the proximal shaft and a prominent caput that has a somewhat concave articulation surface with the rib facets of the dorsal vertebrae.

Coracoid. QMF3567, F2634. In the holotype material, most of the anterior section of both coracoids, as well as the anterolateral and posteromedial part of one coracoid, are preserved (Fig. 5A). Persson (1960) referred another fragmentary, but clearly larger pair of coracoids (QMF2634), consisting of the anteromedial parts, to the same taxon. The author agrees with Persson as the preserved section of the coracoids of QMF2634 are nearly identical with those of QMF3567. In ventral view, a blunt keel follows the coracoidal symphysis, as seen in QMF3567. A very prominent transverse keel is present in about the middle of the anterior section of each coracoid. It becomes larger medially towards the symphyseal surface and is very high and broad in the symphyseal margin, where the keels of both coracoids meet each other. Anteriorly and posteriorly of the keels, the ventral surface is deeply concave. The dorsal surface of the coracoids is slightly convex and only well rounded next to the medial keel. Another fragment belonging to QMF3567 represents the anterolateral articular part of one coracoid, but it cannot clearly be judged whether the right or left one. The scapular articular surface is relatively short compared with the glenoidal fossa. It has a triangular outline in lateral view and is somewhat oriented anteromedially at about 40° to the

vertical plane. The glenoidal fossa is nearly twice as long as the scapular one and has a long oval outline in anterior view. Both facets bear barely preserved rugosities. Medial to the articular part, the bone becomes flattened dorsoventrally. This fragment corresponds well with the preserved anteromedial part. Another fragment of the holotype material represent the most posteromedial part of one coracoid, which is flattened dorsoventrally. The medial edge is straight in its anterior section and medially curved at the posterior end. The latter is slightly thickened and shows a convex curvature.

RMF R271. Both coracoids are almost completely preserved, as only the most posteromedial sections are missing. The coracoid fragments of QMF3567 and F2634 resemble them quite well. For this reason only the posterior part of the coracoid that is not preserved in the other specimens shall be described. The posterior portion of the coracoid forms a broad blade that flares out latcromedially in the most posterior section. Its edges are very thin. The lateral side of each coracoid, between the posterior edge of the glenoid fossa and the transitional from the lateral to the posterior edge is inwardly concave. In dorsal view the posterior edge of the coracoids is slightly curved sigmoidally. From lateral it runs slightly concave to a point at about its medial third and than well convex anteriorly. The medial edge of the posterior portion of the coracoid again is concave and anterolaterally oriented. The intercoracoidal foramen is prominent and about heart-shaped with an accordingly broader anterior portion. The posterior coracoid part is slightly longer than the anterior one.

Remarks. A characteristic feature of the three preserved coracoids is the presence of a prominent transverse keel in the anterior part. Similar keels are present in *Libonectes* (Welles, 1949: fig. 2), *Thalassomedon* (Riggs, 1939: fig. 111), *Hydralmosaurus* (Watson, 1924: fig. 9), *Callawayasaurus* (Welles, 1962: pl. 4), *Mauisaurus* (Welles & Gregg, 1971: fig. 8) and *Tuarangisaurus* (Wiffen & Moisley, 1986: figs 22, 23), but only in *Thalassomedon* and *Hydralmosaurus* are they as prominent as in QMF3567, QMF2634 and RMF R271. The posterior coracoid portions are connected by a large medial symphysis in the early elasmosaurid taxa *Microcleidus* (Watson, 1909: fig. 1), *Occitanosaurus* (Bardet et al., 1999: pl. 3) and *Muraenosaurus* (Andrews, 1910: fig. 62). In *Brancasaurus* this section is incomplete, but a long and rather narrow intercoracoidal foramen has been reconstructed (Wegner, 1914: pl. 9). A prominent intercoracoidal foramen is present in *Callawayasaurus* (Welles, 1962: fig. 6), *Thalassamedon* (Riggs, 1939: fig. 111), *Libonectes* (Welles, 1949: fig. 2), *Styxosaurus* (Welles & Bump, 1949: fig. 4), *Hydralmosaurus* (Welles, 1962: fig. 16) and *Hydrotherosaurus* (Welles, 1962: fig. 20). Of these taxa, the shape of the posterior coracoid portion and the relative proportions of the intercoracoidal foramen in *Thalassamedon*, *Styxosaurus* and *Hydralmosaurus* closely resemble those of Queensland specimens.

Scapula. QMF3567. Of both scapulae only the posterior portions of the glenoid fossa, coracoidal articular surface and the basal sections of the dorsal process are preserved (Fig. 5B). Both, the glenoid fossa and the coracoidal articular surface bear heavy rugosities and have a triangular outline in posterior view. The coracoidal articular surface is about 1.5 × as wide as the glenoid fossa. The latter is anteriorly oriented with an angle of about 60°. The basal section of the dorsal process is situated on the dorsomedial side of the fragment. Its surface as preserved has a slight medial orientation and its posterior edge is away from the lateral corner of the glenoid fossa, at a distance that is about equal with the length of the coracoidal facet. Towards the base of the dorsal process the upper surface of the scapula is dorsally convex. The lateral side of the scapula is flat and only at the level of the dorsal process somewhat concave. The medial side of the scapula bears a sharp edge that emerges posteriorly out of the surface of the coracoidal articular surface and forms the lateral edge of the scapular foramen. The ventral side of the scapula is flat and only somewhat curved posteriorly towards the articulation surfaces.

RMF R271. Both scapulae are almost completely preserved (Fig. 5C), in which in both only parts of the dorsal process are missing. The distal section resembles that of QMF3567 and shall therefore not be described. The medial side of the shaft is, in ventral view, slightly concave. Along the midline of the ventral side of each scapula a rather broad ridge is present, starting at the lateral edge of the glenoid fossa and running with a slight convex curvature to the middle of the anterior end of the scapula. Here the ridge separates the medial part of the anterior scapula and the dorsal process. The medial part of the anterior portion of the scapular is expanded medially. Its ventral surface is plain. The long axis of the dorsal process is oriented at an angle of about 120° to the medial shaft. Its lateral surface is clearly concave. The dorsal process is most

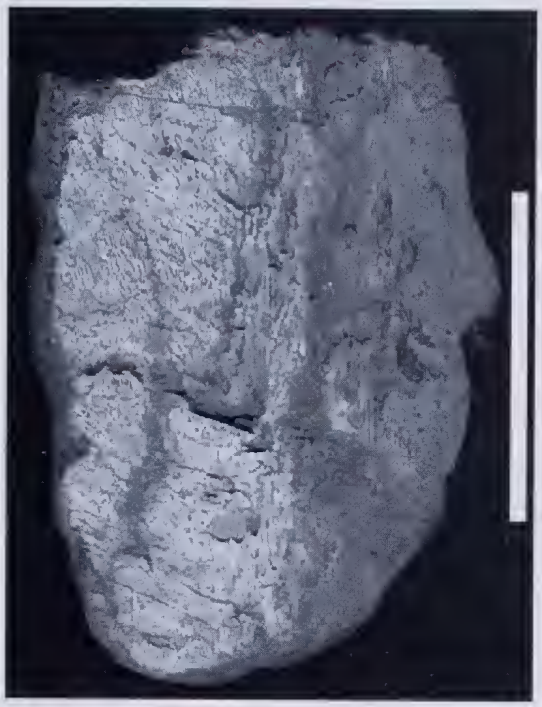

FIG. 6. QMF3567; ?interclavicle fragment in ventral view. Scale = 3cm.

complete in the left scapula. From the anteromedial corner the anterior edge of the dorsal process runs lateroventrally at an angle of about 60° to the horizontal. In anterior view both sections run lateromedially away from each other in a wide V. Dorsally, the surface medial to the dorsal process is clearly concave.

Remarks. It is synapomorphic among elasmosaurids that the coracoidal surface of the scapula is larger than the glenoid fossa (mostly by about 1.5 ×). The angle by which the surfaces stand to each other is variable between taxa. The shaft of the scapula, while proportionally long in RMF R271, is shorter in *Microcleidus* (Watson, 1909: fig. 1), *Occitanosaurus* (Bardet et al., 1999: pl. 3) and *Brancasaurus* (Wegner, 1914: pl. 9). In these taxa the dorsal process is also rather slender and posterodorsally expanded. The dorsal process is not as slender in *Muraenosaurus*, but still more elongate than in RMF R271 (Andrews, 1910: pl. 6). In *Callawayasaurus*, the dorsal process is also more elongate than in RMF R271 and so is the anteromedial section of the scapula (Welles, 1962: pl. 4). In *Libonectes* the shaft of the scapula is similar to those of the Queensland specimens, but is more robust and posteriorly curved in the anteromedial section (Welles, 1949: fig. 2). This is also the case in *Elasmosaurus* (Welles, 1943: fig. 4) and *Thalassamedon* (Welles, 1943: pl. 23). In the later, the dorsal process is also almost vertically directed. In *Hydrotherosaurus*, the scapula is more robust and medially oriented in the anterior sections and here also more medially expanded than in RMF R271 (Welles, 1943: fig. 8). Of *Hydralmosaurus* scapulae are present in AMNH 5835. They are similar to those of RMF R271, but more robust in the anteromedial sections (Welles, 1962: fig. 17). The scapulae of *Styxosaurus* (Welles & Bump, 1949: fig. 4) are very similar to those of the Richmond specimen, except that the shaft is somewhat shorter and the dorsal process is seemingly more expanded.

? Interclavicle. QMF3567. The present fragment is incompletely preserved (Fig. 6). The dorsal surface of the fragment is flat, while on the ventral surface the base of a sagittal keel is apparent. On both sides of the keel the surface is slightly concave. This fragment closely resembles a fragment of the holotype material of *Thalassomedon hanningtoni* (DMNH 1588), which Welles (1943: fig. 14) described as part of an interclavicle.

Clavicles. RMF R271. Both clavicles are present in the Richmond specimen. The left one is almost complete, while of the right only the most anterior section is preserved (Fig. 7). The clavicular symphysis is straight and only barely visible. Ventrally the surface on both edges of the symphyses is slightly thickened and convex, forming an anteroposteriorly running ridge that is better preserved in the anterior portion. Each clavicle wing is posteriorly oriented by an angle of about 115° of its long axis to the symphysis. Thus they are divided from each other by a wide angle, giving them a boomerang-like outline. The ventral surfaces of the bones are slightly convex and only the posterior edge is clearly inclined ventrally. The posterior part of the clavicles is preserved on the left one. It shows that the bone becomes narrower lateromedially towards its posterior end. The posteriormost preserved section is slightly convex in cross-section, and flattened dorsoventrally.

Remarks. Clavicles are only known in a few elasmosaur taxa. They have been described or figured for *Occitanosaurus* (Bardet et al., 1999, plate 3), *Microcleidus* (Watson, 1909: fig. 1), *Muraenosaurus* (Andrews, 1913: pl. 6), *Brancasaurus* (Wegner, 1914. pl. 9), *Thalassamedon* (Welles, 1943. pl. 23), *Callawayasaurus* (Welles, 1962: pl. 4), *Hydralmosaurus* (Welles, 1962: fig. 17) and *Libonectes* (Welles, 1949: fig. 2). In early

taxa such as *Occitanosaurus*, *Muraenosaurus*, *Microcleidus* and *Brancasaurus*, the clavicles are rather short and not boomerang like shaped as in RMF R271. In *Libonectes* each clavicle wing is anteroposteriorly slender in its midsection and the anterior and posterior ends of the clavicular symphysis are separated. In *Hydralmosaurus* the clavicles are incomplete and in *Thalassamedon* they are less curved posteriorly and together form a rather straight posterior surface. In *Callawayasaurus* the clavicles are similar to RMF R271 in general shape, but they are clearly shorter lateromedially.

Humerus. QMF3567, F3568. The holotype material includes the right humerus (Fig. 8A). This element is badly crushed and lacks the posterior mid-shaft section. Persson (1960) referred another, left, humerus (QM F3568) to the same individual, although its locality and the identity of the collector are unknown. As this specimen perfectly corresponds with the humerus of QMF3567, in shape and size, the author agrees with Persson's referral. This second specimen is less crushed than the preserved right humerus, but lacks the entire articular surface for the ulna. In general, the humeri are very stout and about one fifth longer than the femora. The capitulum is very prominent and occupies about two third of the proximal surface of the humerus. In proximal view, it has a broad oval outline, in anterior view it is very convex. The tuberosity is situated at a somewhat lower level than the capitulum, and proximally is separated from it by a shallow fossa. The tuberosity is also slightly displaced posteriorly. The entire proximal articulation surface is broader than the proximal shaft. The shaft is very short and robust and especially proximally broad oval in cross-section. Distally, it becomes gradually flattened lateromedially to a point in the lower third of the bone's length and then rapidly to the distal articulation surface. The distal portion of the bone widens anteroposteriorly. The radial articular surface is 1.5 × larger in area than the ulnar one. Both articular surfaces are slightly concave and mediodistally directed in lateral aspect. At the intersection of both articular surfaces there is a broad, blunt tip. The whole distal surface is inwardly concave. On the anterodistal side, a sharp ridge is present, extending onto the middle of the shaft. The posterodistal surface also bears a ridge along its edge about half as long as the anterior one.

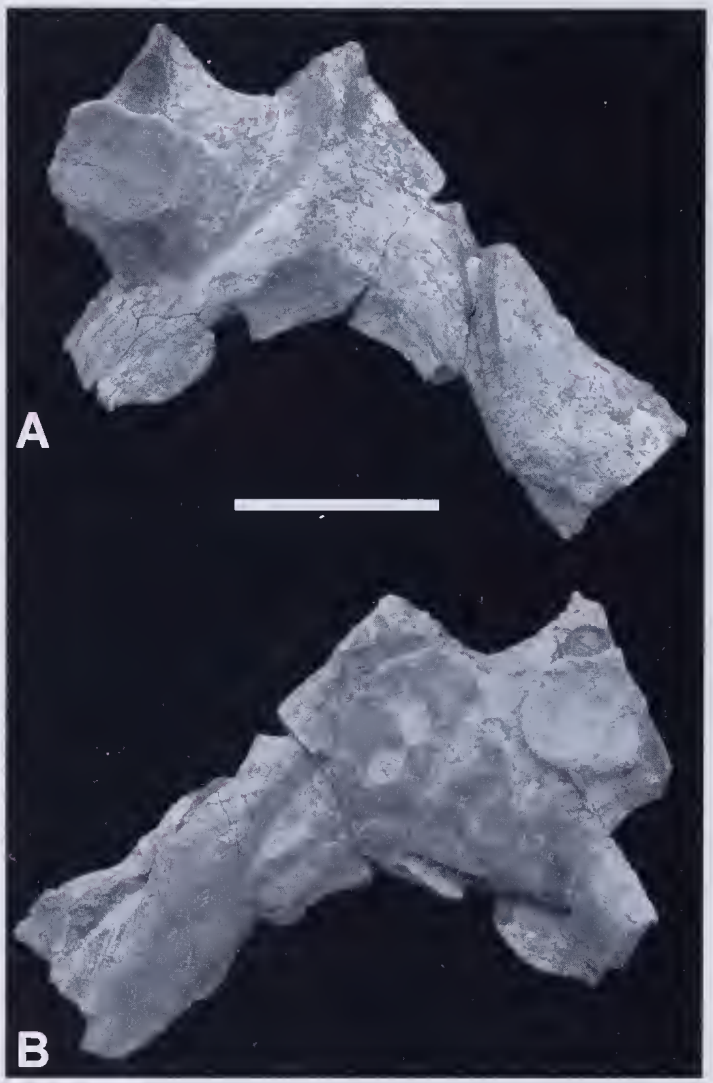

FIG. 7. RMF R271; clavicles in ventral (A) and dorsal (B) view. The flat element attached with the left clavicula arch might belong to a girdle element. Scale = 10cm.

FIG. 8. A, Pectoral paddle. Humerus (QMF3568), radius, ulna, carpalia and metapodial elements (QMF3567). B, RMF R271, left humerus. C, QMF3567, pelvic paddle, showing the femur, fibula and ?metatarsal. D, RMF R271, right femur. Scales = 10cm.

RMF R271. Both humeri are preserved (Fig. 8B). Of these the right one is complete, while the left one is missing the distal articulation surfaces. Their shape resembles well that of the humeri of QMF3567 and F3568, except that the posterior edge of the shaft is more prominently convex.

Remarks. In early elasmosaurs such as *Occitanosaurus* (Bardet et al., 1999: pl. 3), *Muraenosaurus* (Andrews, 1910: pl. 5), *Microcleidus* (Watson, 1911: fig. 2) and *Brancasaurus* (Wegner, 1914: pl. 9), the humeri and femora are not very distinct from each other in size and shape and can be described as rather long and gracile. The size difference of the femur and humerus of the Queensland specimen may relate to ontogenetic stage, so that this cannot be taken as a taxonomic feature. The general shape and proportions are very similar to those of the humeri of *Styxosaurus snowii* (Welles & Bump, 1949: fig. 5).

Ulna. QMF3567. Only one ulna is preserved (Fig. 8A). It is almost quadratic in outline in lateral view. The proximal margin is the longest side of the bone. Its medial margin is oriented anterodistally at an angle of about 45° to the horizontal. The anterior side of the ulna is the shortest. It bears a notch in its mid-surface that is deeper medially than laterally. The distal surface of the ulna is slightly shorter than the proximal one. At its most anterior section, where it connects to the intermedium, the distal margin is oblique proximally at an angle of about 40° to the horizontal. The distal and the proximal surfaces are long oval in outline in distal and proximal aspect. The posterior margin of the ulna is straight and almost as long as the proximal one. It is lateromedially flattened, and bears a blunt crest.

Remarks. The shape of the ulna varies within the genera of the Elasmosauridae. In early elasmosaurids, such as *Occitanosaurus* (Bardet et al., 1999: pl. 3) and *Microcleidus* (Watson, 1911: fig. 2) the ulna is a semi-circular element, while in *Muraenosaurus* (Andrews, 1910: pl. 4) and *Hydrotherosaurus* (Welles, 1943: pl. 19) its outline is more rectangular in lateral view. The rather quadratic shape of QMF3567 is also found in *Styxosaurus* (Welles & Bump, 1949: fig. 5), *Thalassomedon* (Riggs, 1939: fig. 111), *Terminonatator* (Sato, 2003: fig. 13), *Callawayasaurus* (Welles, 1962) and *Mauisaurus* (Welles & Gregg, 1971: fig. 9).

Radius. QMF3567. The radius is broader and more robust than the ulna, but has a similar size and is almost quadratic in outline (Fig. 8A). The distal surface is long oval in outline and relatively broad in distal view. The posterior side is the shortest, and bears a broad notch in its mid-section that is deeper medially than laterally. The proximal and distal surfaces are equally shaped, but the proximal surface is oriented posterodistally at an angle of about 30° to the horizontal. The anterior surface is somewhat longer than the distal one and rather straight. Its edge bears a blunt crest that is relatively smaller than that of the ulna. In contrast to the ulna, a clearly deeper depression is developed at the medial surface of the bone.

Remarks. Mostly the radius is clearly larger than the ulna as in *Muraenosaurus* (Andrews, 1910: fig. 63), *Terminonatator* (Sato, 2003: fig. 13) or *Thalassomedon* (Riggs, 1939: fig. 111 – here the radius was determined as ulna). In *Styxosaurus*, however, the radius and ulna are about the same size as each other. In most elasmosaurids, the shape of the ulna is roughly rectangular. This condition is seen in *Occitanosaurus* (Bardet et al., 1999: pl. 3), *Microcleidus* (Watson, 1911: fig. 2), *Hydralmosaurus* (Watson, 1909: fig. 9), *Hydrotherosaurus* (Welles, 1943: pl. 13), *Mauisaurus* (Welles & Gregg, 1971: fig. 7) and *Thalassomedon*. A similar, more quadratic radius is present in *Muraenosaurus* (Andrews, 1910: fig. 63), *Libonectes* (Welles, 1949: fig. 3), *Callawayasaurus* (Welles, 1962: pl. 4) and *Styxosaurus* (Welles & Bump, 1949: fig. 5).

Carpalia. QMF3567. There are 9 carpals represented in the holotype material (Fig. 8A). Because of the bad preservation only the intermedium clearly could be identified. In relation to the tarsal and the fibula, the carpalia are clearly more thickened and more robust, so probably belong into the fore-paddle. One element is somewhat larger and of about quadratic shape and is interpreted as either the radiale or the ulnare. The intermedium is roughly hexagonal in outline, with all its sides approximately the same length. It also is relatively robust and clearly broader than the fibula. Therefore it might represent the intermedium of the fore-paddle.

RMF R271. An in situ block contains in original arrangement the radiale and intermedium. Only the anteroventral surface of the radiale is preserved, while the intermedium is complete and resembles in shape that of QMF3567.

Metapodials/Phalanges. QMF3567. Two ?metacarpals and one phalange are included in the holotype material (Fig. 8A). The ?metacarpals, of which one is completely preserved, while the other is only represented by its proximal section, are very robust and are interpreted as belonging to the fore-paddle. They are elongate dorsoventrally, constricted on the anterior and posterior sides and have a broadened proximal end that is broad-oval in proximal view. The preserved phalange is only about half as large as the ?metacarpal. It is stout and not much higher than it's wide. It is therefore interpreted as belonging to the distal portion of the paddle.

RMF R271. The metacarpal I-III, as well as seven phalanges are preserved, which because of their size, can clearly be determined as belonging to the pectoral paddle. The metacarpals are of circular shape and are somewhat shorter than the proximal phalanges. In addition, 19 phalanges are present. It cannot be determined whether these elements belong to the pectoral or pelvic paddle.

Femur. QMF3567. Both femora are presented in the material of QMF3567 (Fig. 8C). The right femur is completely preserved, while the left is missing its antero- and posterodistal surfaces. The femora are relatively stout and robust, but clearly more slender than the humeri. Their proximal articular surface bears a prominent capitulum that is nearly circular in outline in proximal view. In anterior view it can be seen that the capitulum clearly slopes down, at an angle of about 45° to the horizontal. The trochanter is situated medially; it is separated from the capitulum by a shallow dorsoventral depression in the posterior surface. The entire proximal surface of the trochanter is distally oriented and eroded in both specimens. It also is weakly constricted from the proximal portion of the shaft. The shaft is relatively short and has equally slightly curved anterior and posterior edges. In cross-section it is nearly circular proximally, becoming flattened anteroposteriorly in about its distal fourth. A crest like structure is present at the junction of the anterior and posterior edges. Of these the posterior one is very prominent and reaches to the proximal end of the lower third of the bone. The anterior crest is somewhat shorter than the posterior one and terminates in the proximal end of the lower fourth of the bone-length. The articulation facets of the tibia and fibula are well preserved in the right femur. The fibular facet is about 1.5 × larger than the tibial one. Its surface is nearly straight in lateral

view, while the tibial facet is clearly proximally curved and therefore slightly convex. At the intersection of both facets a broad, very shallow tip is developed. In distal view, the distal end of the femur has an elliptical outline and is somewhat inwardly concave.

RMF R271. The general shape of the femur resembles that of the femora of QMF3567. Only the distal surface is differently shaped (Fig. 8D), in which no lip-projections are present on the anterior and posterior side and the articular surfaces are not as well developed as in QMF3567. The latter might partially be due to erosion.

Remarks. As with the humeri, the size of the femora can vary during ontogeny. The only femora of similar shape to that of QMF3567 and RMF R271 are those of *Styxosaurus* (Welles & Bump, 1949: fig. 5), *Hydralmosaurus* (Welles, 1962: fig. 16), *Terminonatator* (Sato, 2003: fig. 13) and *Callawayasaurus* (Welles, 1962: pl. 4). In QMF3567, *Styxosaurus*, *Callawayasaurus* and *Terminonatator*, the anterior and posterior sides of the shaft are about equally slightly concave, but in *Hydralmosaurus* the anterior side is rather straight and the posterior one strongly concave

Fibula. QMF3567. In the material of QMF3567, there is an eroded, somewhat pentagonal shaped bone that is interpreted as the left fibula (Fig. 8C). It is clearly smaller and more slender in latero-medial diameter than the radius and ulna. The proximal side is nearly straight and moderately thickened lateromedially. The posterior side of the element is slightly convex. The articular facets for the fibulare and intermedium are about equal in lengths and are anterodistally directed at an angle of about 45° to the horizontal. The fibulare facet is somewhat more thickened lateromedially. Of both facets the intermedium one is the largest. The anterior side of the fibula is the smallest side of the bone. Its entire surface is concave.

RMF R271. One ?fibula is present in the Richmond material. It resembles the shape of that present in QMF3567 and shall therefore not be described.

Remarks. The fibula is mostly more rectangular in shape as it can be found in *Occitanosaurus* (Bardet et al., 1999: pl. 4), *Thalassomedon* (Welles, 1943: pl. 24), *Hydrotherosaurus* (Welles, 1962: fig. 16), *Muraenosaurus* (Andrews, 1910: pl. 4) and *Mauisaurus* (Welles & Gregg, 1971: fig. 4, here wrongly determined as a tibia). In *Styxosaurus* (Welles & Bump, 1949: fig. 5), *Terminonatator* (Sato, 2003: fig. 13) and *Hydralmosaurus* (Welles, 1962: fig. 16) the shape of the fibula is more quadratic in outline. Distally, the articular facets are usually oriented at a lower angle to each other than in the fibula of QMF3567. In addition, the fibulare facet is mostly somewhat larger than the intermedium one (e.g. in *Occitanosaurus*, Bardet et al., 1999, *Thalassamedon*, Welles, 1943 and *Hydralmosaurus*, Welles, 1962). The fibula is similar in size and shape to that of *Callawayasaurus* (Welles, 1962: fig. 5).

Tarsalia. QMF3567. Only a single element could be identified as tarsal (Fig. 8C). It is more flattened than the other mesopodials of similar size and has a rectangular outline. At one side, the edge is crest-like and is slightly concave. The sides opposite of the latter, as well as the proximal and distal surfaces are broader. In comparison, it is very similar with the first tarsal of *Styxosaurus*, shown by Welles & Bump (1949: fig. 5), but somewhat more dorsoventrally elongate in shape.

Pubis. RMF R271. The pubes are incompletely preserved and represented by both symphysial sections, as well as the articular facets for the ischium and acetabulum on the right pubis. The symphysis that is completely preserved on the right pubis is almost straight. The medial part of the pubis is thickened dorsoventrally. In about the middle of the symphysial surface a broad, low ridge is visible dorsally. The medial surface also bears slight rugosities. At the most anterior section the symphysial surface becomes somewhat lower dorsoventrally and is slightly anterolaterally directed. The posterior edge of the pubis that formed the anterior frame of the foramen obturatum is very thin and, as preserved, slightly inwardly concave. The articulation section is massively developed. Both articulation facets stand to each other by an angle of about 110°. The acetabular surface is about 1.5 × the size of the ischial one and is somewhat depressed. In posterior view the acetabular surface has a broad-oval outline. The ischial surface is triangular in shape; the facet surface is plain and bears rugosities.

? Pubis. QMF3567. Only two fragments have been identified as belonging to the pubes. One represents the posteromedial articulation section. It comprises two facets, a small facet to the ischium and a large facet that forms the anterior section of the acetabulum. The facet to the ischium is triangular in outline and has a nearly

straight articular surface that bears rugosities. The acetabular section is about twice as long as the ischial one and projects anterolaterally at an angle of about 45° to the horizontal. At the anterior side of the acetabular facet a thin edge is developed, running anteriorly. While the dorsal side of the fragment is strongly convex, the ventral surface is rather straight. In the holotype material, there is another fragment that clearly belongs to a girdle-element. After a detailed comparison, this fragment seems to appear in the medial part of the pubis. Its dorsal surface is shallowly concave, while the ventral surface is convex on one (probably the medial) side, where an articulation surface is developed. This surface probably represents the interpubic symphysis. It is relatively straight and bears some rugosities.

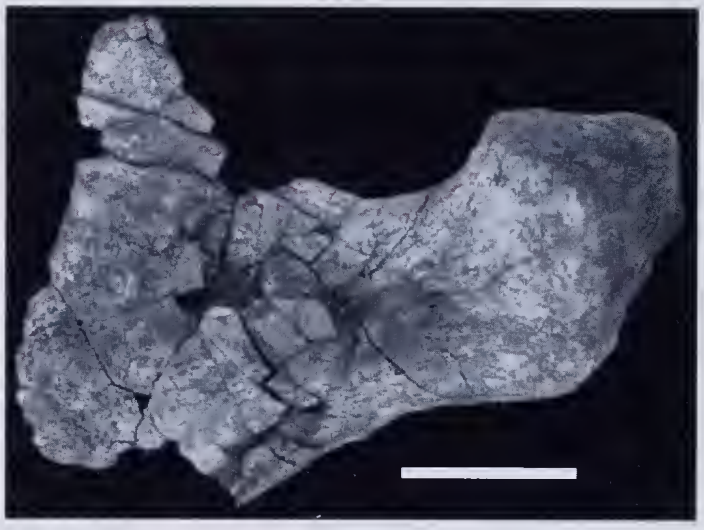

FIG. 9. RMF R271; right ischium in dorsal view. Scale = 5cm.

Remarks. In *Microcleidus* and *Occitanosaurus* the anterior section of the interpubic symphysis is strongly oriented anterolaterally and also the ischial and acetabular surfaces in these taxa stand to each other in a wider angle than in RMF R271 (Watson, 1909: fig. 11; Bardet et al., 1999: pl. 4). This is the case in *Muraenosaurus* too, where the acetabular surface is also clearly more prominent than in RMF R271 (Andrews, 1910: fig. 65). In *Brancasaurus* the anterior section of the medial symphysis is strongly oblique anterolaterally, the acetabular facet is about twice as large as the ischial one and the edge of the foramen obturatum is narrower and more concave than in the Richmond specimen (Wegner, 1914: pl. 9). *Hydralmosaurus* has a shorter medial symphysis and the edge for the foramen obturatum is more concave and narrower than in RMF R271. Also the most anteromedial section is clearly oblique laterally (Welles, 1962: fig. 16). In *Thalassamedon* a shorter interpubic symphysis is developed that shows no vault in the midsection and the edge of the foramen obturatum is wider than that in RMF R271 (Welles, 1943, pl. 23). In *Hydrotherosaurus* a very prominent acetabular articulation surface is present, which is clearly more prominent than the ischial one. The edge for the foramen obturatum is narrower and more concave than in RMF R271 and the interpubic symphysis is strongly curved laterally in the anterior half (Welles, 1943, fig. 9). *Elasmosaurus* has a narrower and more concave edge of the foramen obturatum, the anterior section of the pubis is well oblique anterolaterally and the acetabular articulation surface is about twice as long as the ischial one (Welles, 1963, fig. 14). The pubis of *Mauisaurus* is rather similar to RMF R271, only the interpubic symphysis is straight for its entire length (Welles & Gregg, 1971: fig. 4). In *Callawayasaurus* the edge of the foramen obturatum is narrower, but similarly slightly concave than in RMF R271 (Welles, 1962, plate 4). The pubis of *Styxosaurus* resembles in its general shape that of RMF R271 (Welles & Bump, 1949, fig. 4).

?Ilium. QMF3567. A fragment in the holotype material is interpreted as to be the ventral part of an ilium. The ventral section, that bears the articulation surface, is somewhat thickened. Above the articulation surface, the bone is more or less quadratic in cross-section. The anterior and proposed medial side of the fragment are about equal in length and have a nearly flat surface. The proposed lateral side, as well as the posterior one are strongly outwardly curved. The posterior side is shorter than the others. The dorsal end of the fragment is vertically oval in cross-section.

Ischium. RMF R271. Both ischia are present. The right one is almost complete, while of the left only the medial section is preserved (Fig. 9). The interischial symphysis is rather straight and only in its posterior third slightly posterolaterally curved. The symphyseal surface thins out dorsoventrally in about the posterior third,

	QMF3567				RMF R271		
	Length	Width	Height		Length	Width	Height
Axis	3.5	ca. 2.5	ca. 2.5				
CV 1	5	4.8	3.2	CV 1	8	6	4.8
CV 2	5	4.8	3.2	CV 3	6.5	7	5.2
CV 3	4.8	5	3.6	CV 3	6.4	7 i.c.	5.5
CV 7	5 ic	4.3 ic	3.3 ic	CV 3	7	7.5 i.c.	5.5
CV 5	6.3	5.1 ic	4.6	CV 5	4.8	8	nm
CV 6	6.3	4.8	4.3	CV 6	6.5	8	8
CV 7	6.6	6.1	4.6	CV 7	6.8	7.5	5.5
CV 8	6.7	6.2	4.8	CV 8	6.3	6 i.c.	7.8
CV 9	7.3	7.6	5.4	CV 8	6.2	8 i.c.	8
CV 10	7.4	7.2 ic	6.5	CV 10	6.8	7.8	4.8
CV 11	7.9 ic	6.4 ic	5.6	CV 11	6.5	8	6 i.c.
CV 12	7.8	8	6.1	CV 12	6.5	8	6
CV 14	7.5	8 ic	6.2	CV 13	6.2	8.5 i.c.	4.8
CV 14	7.2	8.5 ic	6.4	CV 14	6.8	8.5 i.c.	6.5
CV 15	7.1	8 ic	6.4	CV 15	6.3	6.7	8
CV 18	7.8	8.5	6.3				
CV 17	7.6	8.3 ic	6.3				
CV 18	7.2	9.2	6.4				
CV 19	7.8	8.1	6.4				
CV 20	7.1	8.5 ic	6.4				
CV 21	7.2	8 ic	6.4				
CV 22	6.8	9.4 ic	6.7				
CV 24	6.8	9.8	6.8				
CV 24	7.1	9.7	6.8				
PV 1	7	6.5	7.2	PV 1	6.4	4.3	6.2
PV 2	7	9.3 ic	6.8	PV 2	6.3	nm	8
PV 3	7	9.7	6.5	PV 3	6.5	9.4	6.3
DV 1	7.2	8.5	7.4	DV 1	6.2	9.3	4.8
DV 2	7	8.5 ic	7.2	DV 2	6	8.8	6.2
DV 4	6.8	6.5	7.5	DV 3	6.4	8.8	6.8
DV 4	6.8	8.3	7.5	DV 4	6.4	8	6.4
DV 5	6.5	8.1	7.3	DV 5	6.2	nm	6.5
DV 8	6.8	8	7.9	DV 6	5	6.5	5
DV 7	6.7	7.8	7	DV 7	nm	7.2	nm
DV 8	6.4	7.8	7	DV 8	8	nm	nm
DV 9	5.2	7.2	5.8	DV 8	nm	6.5	6.5
				DV 16	nm	7.5	4.8
				DV 11	nm	8	7.8
				DV 12	nm	7.8	4.8
				DV 13	4.8	7.8	4.8
				DV 14	5.4	7.7	8
				DV 15	5	7.8	5.6
				DV 16	6.2	7.8	nm
				DV 17	5	7.2	5.4
CAV 1	4.8	7.7	5.5	CAV 1	4.3	7	5.5
CAV 2	7.8	7.3	5.7	CAV 2	4	7.4	6
CAV 3	4.2	8	5.6	CAV 3	4.3	nm	4.8
CAV 4	4.5	7.8	4.7 ic	CAV 4	3.8	6.8	5.4
CAV 5	4.8	7	5.7	CAV 5	8.1	4.8	6.7
CAV 6	4.2	6.8	5.4	CAV 6	3.9	6.7	5.4
CAV 7	4.5	nm	nm	CAV 7	3.6	4.8	5.3
SV 1	5.3	7.4	5.8	CAV 8	3.2	5.8	4.9
SV 2	5	7.1	5.5	CAV 9	3.8	6.2	5.5
SV 3	4.6	7.6	5.3	CAV 10	3.4	nm	nm

TABLE 1. Measurements (in cm) of the vertebrae of QMF3567 and RMF R271. CV = Cervical vertebrae; PV = pectoral vertebrae; DV = dorsal vertebrae; SV = sacral vertebrae; CAV = caudal vertebrae; ic = incomplete; nm = not measurable.

towards the posterior end. The anterior surface of the ischium is very thin and inwardly curved, forming the posterior frame of the foramen obturatum that is wide and well concave. The posterior side of the ischium is posteromedially curved, from the posterior border of the acetabular surface to the posterior end of the symphysis. In medial view the symphysis is very slightly sigmoidally curved. The laterally situated articulation facets are very massive. The pubic surface has a triangular outline in anterior view and bears some weak rugosities. The acetabular surface has about 1.5 × the size of the pubic one and is somewhat triangular in outline. It is more expanded posteriorly and its posterodorsal surface slightly oriented ventrally. In general the ventral surface of the ischium is slightly convex, the dorsal one slightly concavely formed.

QMF3567. One fragment represents the most posteromedial part of an ischium. Its medial surface is thickened dorsoventrally, but corroded. The preserved lateral edge is thin, but not sharp. It is strongly curved posterolaterally.

Remarks. In *Occitanosaurus*, *Brancasaurus* and *Muraenosaurus* the ischia are more expanded mediolaterally, the edges of the foramina obturata are deeply concave and the acetabular facet is larger compared with the ischial one, than in RMF R271 (Bardet et al., 1999; Wegner, 1914; Andrews, 1910). In *Microcleidus* the ischia are more expanded anteroposteriorly and the edge of the foramen obturatum is more oriented posteromedially than in RMF R271 (Watson, 1909: fig. 11). In *Mauisaurus* the acetabular surface is larger and the posterior edge more concave than in RMF R271 (Welles & Gregg, 1971: fig. 8). In *Callawayasaurus* the ischium is generally more slender and posteromedially expanded, the edge for the foramen obturatum is posteromedially oriented and the acetabular surface is more prominent in relation to the pubic one as in RMF R271 (Welles, 1962: fig. 6). This is also the case in *Hydrotherosaurus*, except that the edge for the foramen obturatum is not as strongly oriented posteromedially (Welles, 1962: fig. 20). In *Hydralmosaurus* the edge for the foramen obturatum is less anteriorly curved in the medial section, the ischia are more robust and seem to be

TABLE 2. Measurements (in cm) of QMF3567 and RMF R271.

QMF3567		RMF R271	
Scapula (left)		Scapula (left)	
Anteroposterior length	16.6 ic	Anteroposterior length	32
Diameter of distal articulation surface	11.7	Width of distal articulation surface	12.5
Diameter of glenoidal surface	5.8	Diameter of glenoidal surface	6.5
Diameter of coracoidal surface	5.5	Diameter of coracoidal surface	6.5
Length of glenoidal surface	5.8	Length of glenoidal surface	7
Length of coracoidal surface	7	Length of coracoidal surface	9.3
		Width of the anterior end	13
		Length anteropost. of dorsal process	24
		Dorsal process, greatest preserved expansion	10
Scapula (right)		Scapula (right)	
Anteroposterior length	19.5 ic	Anteroposterior length	29
Diameter of distal articulation surface	12.5	Width of distal articulation surface	12.5
Diameter of glenoidal surface	4.5 ic	Diameter of glenoidal surface	7
Diameter of coracoidal surface	4.8 ic	Diameter of coracoidal surface	6.5
Length of glenoidal surface	5.8	Length of glenoidal surface	7
Length of coracoidal surface	7.4	Length of coracoidal surface	7
		Width of the anterior end	12
		Length anteropost. of dorsal process	21
		Dorsal process, greatest preserved expansion	8
Coracoid (left)		Coracoid (left)	
Anteroposterior length	18 ic	Anteroposterior length	44 ic
Length of glenoidal surface	9.5	Length of glenoidal surface	8
Length of scapular surface	7.5	Length of scapular surface	7
Transverse expansion of medial vault	11	Transverse expansion of medial vault	7.5
		Width of posterior blade	29
		Length of anterior symphysis	20 ic
Coracoid (right)		Coracoid (right)	
Anteroposterior length	24 ic	Anteroposterior length	44 ic
Width of posterior blade			25.5
Length of glenoidal surface	nm	Length of glenoidal surface	11
Length of scapular surface	nm	Length of scapular surface	8
Length of anterior symphysis			23.5
Transverse expansion of medial vault	nm	Transverse expansion of medial vault	7.5
?Interclavicle		Clavicles	
Length anteroposteriorly	6 ic	Length anteroposteriorly, left	24.5 ic
Height dorsoventrally	2.3	Length anteroposteriorly, right	18 ic
		Length of symphysis	11.5
Humerus (left; QMF3568)		Humerus (left)	
Total length	31.5	Total length	32
Width distal	20	Width distal	18 ic
Lateromedial diameter of capitulum	3.5	Lateromedial diameter of capitulum	6.5
Lateromedial diameter of tuberosity	7.5	Lateromedial diameter of tuberosity	2.8
Anteroposterior diameter of capitulum	10.2	Anteroposterior diameter of capitulum	8
Anteroposterior diameter of tuberosity	10.7	Anteroposterior diameter of tuberosity	8.2
Humerus (right)		Humerus (right)	
Total length	31.5	Total length	26 ic
Width distal	nm	Width distal	nm
Lateromedial diameter of capitulum	7.4	Lateromedial diameter of capitulum	nm
Lateromedial diameter of tuberosity	3.9	Lateromedial diameter of tuberosity	nm
Anteroposterior diameter of capitulum	9.8	Anteroposterior diameter of capitulum	nm
Anteroposterior diameter of tuberosity	10.6	Anteroposterior diameter of tuberosity	nm

TABLE 2 (*Cont.*)

Ulna		Intermedium manus	
Anteroposterior length	10.5	Lateromedial width	7
Dorsoventral height	10.3	Dorsoventral height	6
Lateromedial diameter	7.2	Radiale manus	
Radius		Width	7.2
Anteroposterior length	11.4	MC I	
Dorsoventral height	10.5	Lateromedial width	5.5
Lateromedial diameter	5.4	Dorsoventral height	5.5
Intermedium manus		MC II - Lateromedial width	6
Lateromedially diameter	7	Dorsoventral height	5.2
Dorsoventral height	6	MC III – Lateromedial width	6.5
		Dorsoventral height	6.2
Femur (left)		Femur (left)	
Total length	27.5	Total length	nm
Width distal	18	Width distal	14
Lateromedial diameter of trochanter	4.3	Lateromedial diameter of trochanter	2
Lateromedial diameter of capitulum	6.5	Lateromedial diameter of capitulum	10
Anteroposterior diameter of trochanter	7.2	Anteroposterior diameter of trochanter	5.2
Anteroposterior diameter of capitulum	6.5	Anteroposterior diameter of capitulum	7.6
Femur (right)		Femur (right)	
Total length	26.5 ic	Total length	31
Width distal	nm	Width distal	16
Lateromedial diameter of trochanter	3.8	Lateromedial diameter of trochanter	nm
Lateromedial diameter of capitulum	7	Lateromedial diameter of capitulum	6
Anteroposterior diameter of Trochanter	7.2	Anteroposterior diameter of trochanter	nm
Anteroposterior diameter of capitulum	6	Anteroposterior diameter of capitulum	6.2
Fibula		Pubis (left)	
Anteroposterior diameter	8.5	Length along symphysis	24.2
Lateromedially diameter	2.5	Length acetabular surface	nm
Dorsoventrally height	6	Length ischial surface	nm
?Metatarsal I		Pubis (right)	
Anteroposterior diameter	5	Length along symphysis	17 ic
Lateromedial diameter	2.1	Length acetabular surface	7
Dorsoventral height	6	Length ischial surface	6
?Ilium		Ischium (left)	
Anteroposterior diameter	7	Width lateromedially	nm
Lateromedial diameter	6	Length along symphysis	20
Dorsoventral height	7.6	Length pubic articular surface	nm
		Length acetabular surface	nm
		Ischium (right)	
		Width lateromedially	21.5
		Length along symphysis	16.5 ic
		Length pubic articular surface	5.2
		Length acetabular surface	10

more expanded posteriorly than in RMF R271. Also the acetabular facet is more prominent in relation to the pubic one than in the Richmond specimen (Welles, 1962: fig. 16). In *Thalassamedon* the edge of the foramen obturatum is wider, the interischial symphysis is straighter and the ischia seem to be more expanded anteroposteriorly than in RMF R271. Also in *Elasmosaurus* the ischia are more elongate anteroposteriorly, the posterior edge is clearly posteriorly curved, the acetabular surface is more prominent and the edge of the foramen

obturatum is narrower but more concave than in RMF R271 (Welles, 1962: fig. 14). In *Styxosaurus* the general shape resembles well that of the ischia of the Richmond specimen, only the posterior edge is more posteriorly oriented (Welles & Bump, 1949: fig. 4).

Unidentified Girdle Elements. There are numerous indeterminable, flat fragments preserved, which seem to belong to parts of the pectoral or pelvic girdle.

CONCLUSIONS

From the above comparisons it is evident that specimens QMF3567, QMF3568, QMF2634 (described as *Woolungasaurus glendowerensis* by Persson; 1960), and RMF R271 are most similar to material referred to *Styxosaurus*. *Styxosaurus* is known by one valid species, *S. snowii*, from the western interior of North America. All specimens so far have been found in sediments of Campanian age (Carpenter, 1999: 158-160), so that the Queensland *Styxosaurus* from the Aptian is the earliest record of this taxon and the first in the Southern Hemisphere.

The main osteological differences between *Styxosaurus snowii* and the Queensland specimens are the absence of a prominent transverse keel on the anterior portion of the coracoid, a more slender scapula, a relatively more slender femur and a fibula with pentagonal outline. All other elements described are almost identical or very similar to those of *Styxosaurus snowii*.

Facts that lead to the conclusion that *Woolungasaurus glendowerensis* is referable to *Styxosaurus* but distinct from *S. snowii* are the smaller size (it probably measured about 5m when fully grown, while the mounted skeleton of *Styxosaurus snowii* SDSM451 measures approximately 11m), its occurrence in the Southern Hemisphere and its older age. On the other hand, in the author's opinion, the differences are sufficient to confirm that *Woolungasaurus* is a junior synonym of *Styxosaurus*.

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LITERATURE CITED

ANDREWS, C. W. 1910. A descriptive catalogue of the marine reptiles of the Oxford Clay. Part 1. British Museum (Natural History): 1-205.

BARDET, N., GODEFROIT, P. & SCIAU, J. 1999. A new elasmosaurid plesiosaur from the Lower Jurassic of southern France. Palaeontology 42(5): 927-952.

BROWN, D.S. 1981. The English Upper Jurassic Plesiosauridea (Reptilia) and a review of the phylogeny and classification of the Plesiosauria. Bulletin of the British Museum (Natural History), Geology series 35(4): 253-347.

CARPENTER, K. 1997. Comparative cranial anatomy of two North American Cretaceous plesiosaurs. Pp. 191-216. In Callaway, J.M. & Nicholls, E.L. (eds) Ancient marine reptiles (Academic Press: San Diego).

1999. Revision of North American elasmosaurs from the Cretaceous of the western interior. Paludicola 2(2): 148-173.

CHATTERJEE, S. & SMALL, B.J. 1989. New plesiosaurs from the Upper Cretaceous of Antarctica. Pp. 197-215. In Crame, J.A. (ed.) Origins and evolution of the Antarctic biota. (Geological Society Special Publication No. 47).

COPE, E.D. 1869. Extinct Batrachia, Reptilia and Aves of North America. Transactions of the American Philosophical Society 14: 1-252.

1877. Report on the geology of the region of the Judith River, Montana, and on the vertebrate fossils obtained on or near the Missouri River. Part 2. Vertebrata from the Niobrara Cretaceous. United States Geological and Geograohical Survey of the Territories, Hayden Survey, Bulletin 3: 565-597.

CRUICKSHANK, A.R., FORDYCE, R.E. & LONG, J.A. 1999. Recent developments in Australasian sauropterygian palaeontology (Reptilia: Sauropterygia). Records of the Western Australian Museum, Supplement No. 57: 201-205.

DAY, R.W. 1969. The Lower Cretaceous of the Great Artesian Basin. Pp. 140-173. In Campbell, K.S.W. (ed.) Stratigraphy and palaeontology. (Australian National Univerity Press: Canberra).

FRAAS, E. 1910. Plesiosauriden aus dem oberen Lias von Holzmaden. Palaeontographica 57: 105-140.

GASPARINI, Z., BARDET, N., MARTIN, J. & FERNANDEZ, M. 2003. The elasmosaurid plesiosaur *Aristonectes* Cabrera from the latest Cretaceous of South America and Antarctica. Journal of Vertebrate Paleontology 23(1): 104-115.

KEAR, B. 2003. Cretaceous marine reptiles of Australia: a review of taxonomy and distribution. Cretaceous Research 24: 277-303.

OWEN, R. 1865. A monograph of the fossil Reptilia of the Liassic formations. Part 3. Monographs of the Palaeontological Society 1865: 1-40.

PERSSON, O. 1960. Lower Cretaceous Plesiosaurians (Reptilia) from Australia. Lunds Universitets Arsskrift 56(12): 1-23.

1963. A revision of the classification of the Plesiosauria with a synopsis of the stratigraphical and geographical distribution of the group. Lunds Universitets Arsskrift 59(1): 1-59.

1982. Elasmosaurid skull from the Lower Cretaceous of Queensland (Reptilia: Sauropterygia). Memoirs of the Queensland Museum 20(3): 647-655.

RIGGS, E. 1939. A specimen of *Elasmosaurus serpentinus*. Field Museum of Natural History, Geological Series 6: 385-391.

SATO, T. 2003. *Terminonatator ponteixensis*, a new elasmosaur (Reptila, Sauropterygia) from the Upper Cretaceous of Saskatchewan. Journal of Vertebrate Paleontology 23(1): 89-103.

SEELEY, H.G. On *Muraenosaurus leedsii*, a plesiosaurian from the Oxford Clay. Part 1. Quarterly Journal of the Geological Society London 30: 197-208.

STORRS, G.W. 1999. An examination of Plesiosauria (Diapsida: Sauropterygia) from the Niobrara Chalk (upper Cretaceous) of central North America. The University of Kansas Paleontological Contributions N.S. 11: 15.

WATSON, D.M. 1909. A preliminary note on two genera of Upper Liassic plesiosaurs. Memoirs and Proceedings of the Manchester Literary and Philosophical Society 54: 1-28.

1911. The Upper Liassic Reptilia. Part 3. *Microcleidus macropterus* (Seeley) and the limbs of *Microcleidus homalospondylus* (Owen). Memoirs and Proceedings of the Manchester Literary and Philosophical Society 55(17): 1-9.

1924. The elasmosaurid shoulder-girdle and fore-limb. Proceedings of the Zoological Society of London 1924: 885-917.

WEGNER, T. 1914. *Brancasaurus brancai* n.g. n. sp., ein Elasmosauride aus dem Wealden Westfalens. Pp. 235-305. In Schoendorf, F. (ed.) Branca Festschrift. (Gebrüder Borntraeger, Berlin).

WELLES, S.P. 1943. Elasmosaurid plesiosaurs with description of new material from California and Colorado. Memoirs of the University of California 13(3): 125-254.

1949. A new elasmosaur from the Eagle Ford Shale of Texas. Fondren Science Series, Southern Methodist University 1: 1-28.

1952. A review of the North American Cretaceous elasmosaurs. University of California Publications in Geological Sciences 29: 47-144.

1962. A new species of elasmosaur from the Aptian of Colombia and a review of the Cretaceous plesiosaurs. University of California Publications in Geological Sciences 46: 1-96.

WELLES, S.P. & BUMP, J. 1949. *Alzadasaurus pembertoni*, a new elasmosaur from the Upper Cretaceous of South Dakota. Journal of Paleontology 23: 521-535.

WELLES, S.P. & GREGG, D.R. 1971. Late Cretaceous marine reptiles of New Zealand. Records of the Canterbury Museum 9(1): 1-111.

WIFFEN, J. & MOISLEY, W. 1986. Late Cretaceous reptiles (Families Elasmosauridae, Pliosauridae) from the Mangahouanga Stream, North Island, New Zealand. New Zealand Journal of Geology and Geophysics 29: 205-252.

WILLISTON, S. 1890. A new plesiosaur from the Niobrara Cretaceous of Kansas. Transactions of the Kansas Academy of Science 12: 174-178.

REPRODUCTION IN PRICKLY FOREST SKINKS, *GNYPETOSCINCUS QUEENSLANDIAE*. *Memoirs of the Queensland Museum 49(2): 732. 2004:-* *Gnypetoscincus queenslandiae* is a rainforest endemic skink abundant in the Wet Tropics of Australia. This species is the subject of extensive studies on both the current and historical effects of fragmentation (Sumner et al., 1999; Cunningham & Moritz, 1998). A more complete knowledge of its ecology is vital when looking at possible effects of fragmentation and determining management strategies. Previous work on the reproductive biology of this species from museum specimens suggested that *G. queenslandiae* give birth between February and April with a clutch size of 2-5 (Cunningham, 1993). Here we look at some aspects of reproduction in live animals.

Eleven gravid female prickly forest skinks were collected from 3 sites on the Atherton Tableland: 4 from Whiteing Rd (145°36°E, 17°34°N), 4 from Sutties Gap Rd (145°34°E, 17°37°N) and 3 from Mt Father Clancy (145°38°E, 17°36°N) — the first a rainforest fragment, the latter two within continuous forest. The skinks were collected late November 1996 and maintained in the lab until parturition. They were housed in separate rectangular 3.5L plastic containers in a 26°C constant temperature room. The containers had approximately 5cm of soil, a rectangle of plastic as cover, and a water dish in which the lizard could immerse itself if disturbed. Soil was maintained at a moist to wet consistency. Lizards were fed cockroaches and mealworms thrice weekly and were checked daily to determine whether they had given birth. They were weighed weekly and at parturition. On discovery, neonates were weighed, measured and placed in separate containers. They were fed thrice weekly, watered daily, and weighed and measured weekly until approximately 5 weeks of age. They were then euthanased and sexed via dissection. Average size of both neonates and mothers were calculated as well as total clutch mass. Statistical analyses were done using STATISTICA™ software.

Females were between 74 and 81mm SVL on capture and weighed from 9.1 to 14.2g (Table 1). All females gave birth between 8-18 January. Thirty-four offspring were born to 11 mothers, with clutch sizes 1-5, and an average of 3.1 (Table 1). Neonate morphology is summarised in Table 2.

Twenty-three neonates could be sexed with confidence: 13 females and 10 males. There was no evidence of sexual dimorphism in *G. queeenslandiae* neonates, despite significant differences in adult morphology (Sumner et al., 1999).

The parturition dates of this study are consistent with Cunningham (1993), who reported gravid females from the Atherton Tableland collected in September, November and December, but not in February (no individuals collected in January). The early parturition date found here may be due to the captive condition of the lizards. The births were in quick succession once the first individual had given birth. Hormonal cues might enhance synchronous parturition.

Cunningham (1993) and Sumner et al., (1999) both found a skewed sex ratio in *G. queenslandiae*. Slightly more female neonates were identified in this study, however the difference is not significant, suggesting that postnatal effects may account for the uneven sex-ratio in these previous studies.

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Literature Cited

CUNNINGHAM, M. 1993. Reproductive biology of the Prickly Forest Skink, Gnypetoscincus queenslandiae, an endemic species from northern Queensland. Memoirs of the Queensland Museum 34: 131-138.

CUNNINGHAM, M. & MORITZ, C. 1998. Genetic effects of forest fragmentation on a rainforest restricted lizard (Scincidae: *Gnypetoscincus queenslandiae*). Biology Conservation 83: 19-30.

SUMNER, J., MORITZ, C. & SHINE, R. 1999. Shrinking forest shrinks skink: morphological change in response to rainforest fragmentation in the prickly forest skink (*Gnypetoscincus queenslandiae*). Biology Conservation 91: 159-167.

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TABLE 1. Clutch data for gravid *Gnypetoscincus queenslandiae*, with number of individuals (No.), minimum (Min.), maximum (Max.), mean and standard error (SE) for each character.

Character	No.	Min.	Max.	Mean	SE
Snout-vent length (mm)	31	74	81	76.66	0.68
Postpartum mass (g)	31	6.67	9.26	7.96	0.26
Clutch size	11	1	5	3.09	0.34
Total clutch mass (g)	9	0.46	2.95	1.76	0.23

TABLE 2. Morphological measurements of neonate *Gnypetoscincus queenslandiae*, with number of individuals (No.), minimum (Min.), maximum (Max.), mean and standard error (SE) for each character.

Character	No.	Min.	Max.	Mean	SE
Snout-vent length (mm)	32	28	31	29.88	0.14
Total length (mm)	32	58	69	64.78	0.49
Inter-limb length (mm)	32	13	16	14.59	0.13
Head length (mm)	32	7.5	8.6	8.02	0.05
Head width (mm)	32	4.6	5.5	5.11	0.04
Mass (g)	32	0.45	0.66	0.56	0.01

REPTILES AND MAMMALS OF FITZROY ISLAND, QUEENSLAND

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Sprackland, R.G., Sprackland, T. & Diessner, D. 2004 06 30: Reptiles and mammals of Fitzroy Island, Queensland. *Memoirs of the Queensland Museum* **49**(2): 733-739. Brisbane. ISSN 0079-8835.

The terrestrial fauna of Fitzroy Island National Park has not hitherto been the focus of a biodiversity survey. During 1999, 2000 and 2003 an extensive faunal survey was conducted, increasing the number of confirmed taxa from one to eighteen reptiles and from one to four mammals. The herpetofaunal and mammalian composition of the island is now known to include three gekkonids, one varanid, ten scincids, one python, two colubrids, two bats, a macropod and a rat. Despite extensive searches, no amphibians were found. ❑ *Reptiles, mammals, island biogeography, biodiversity, Fitzroy Island.*

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Fitzroy Island is one of the largest continental islands along Australia's eastern coast. Located 29km SE of Cairns, Fitzroy Island is separated from the nearest mainland, Cape Grafton peninsula, by a 5km wide channel. Though the island is a national park within the Great Barrier Reef, it has not hitherto been the subject of a biodiversity survey. Because of the island's size, distance from the mainland and geological history, it has remained a comparatively pristine environment, spared serious invasive species such as cane toads. As the end of a long mountain chain, Fitzroy has three peaks in excess of 180m, giving it a considerable terrestrial surface area. These features make Fitzroy Island an attractive laboratory for studies on continental biogeography that would complement the considerable volume of studies of oceanic island systems.

In 1999 the senior author began a survey of the terrestrial fauna of Fitzroy Island, focusing primarily on the reptiles, but including insects, centipedes and mammals. Published information on Fitzroy Island's fauna includes Malone (2001) and Sprackland (2000, 2001a, 2001b, 2001c). This paper presents the herpetofaunal content of the island (Table 1). A detailed description of the vegetation communities is provided in Le Cussan (1997).

MATERIALS AND METHODS

Animals were observed *in situ* during October 1999, August 2000 and June-August and photographed. Identifications were made on site using Cogger (1999), Couper et al. (2000) and Swan (1995).

THE ISLAND ENVIRONMENT

Fitzroy Island is part of a granitic mountain chain that runs in a predominantly N-S direction along coastal Queensland. At the end of the last Ice Age some 6,000BP, the low-lying grassy plain between Fitzroy's 4 peaks and what is now the mainland was flooded by sea. Remaining above the waterline is Little Fitzroy Island at the far east of the chain and the 3 contiguous peaks of larger Fitzroy Island. The main island peaks reach 189, 211 and 269m in height. The larger island is some 339ha in area with maximum length of 3,750m and width of 2,000m. The island is a national park, but small portions of the northern coast house a commercial prawn hatchery and a resort. Queensland Parks and Wildlife Service has a ranger base of several buildings on the easternmost peak (129m) and a concrete access road from the resort to the base. QPWS also has several walking paths around the park, though the majority of the island is inaccessible due to vegetation. A fringing reef surrounds both islands.

The north-facing slopes of the island are lush wet rainforest. Higher elevations and south-facing slopes are drier scrub forest with intermittent open heath (mainly on hillsides) and the east is composed of pandanus palms, mangroves and casuarinas. Annual average temperatures are 28°C (day) and 22.5°C (night).

REPTILES OBSERVED

GEKKONIDAE.

Gehyra dubia (Macleay, 1877). Common around the buildings of the ranger base (elevation 129m)

and the large VIP buildings W of the resort (elevation 10m). Differs very slightly from mainland specimens in the broad rostral having a partial median cleft, nearly dividing the scale in two. Toes with round tips. Subdigital lamellae strongly notched into 2 rows; first lamella of fourth toe triangular, second and third strongly V-shaped, fourth through eighth strongly notched and ninth straight. First digit tiny and clawless. Mental pentagonal; 6 large postmentals, the first in contact with mental and first infralabial. Dorsals granular, subequal. Tail carrot shaped, slightly depressed. Colour variable, from nearly translucent pink to gray with darker symmetrical spots on either side of the vertebral column. Adult SVL 63-68mm; tail 60-63mm.

Egg laying and hatching occurred in June and July. Males have enlarged postanal sacs. Active from dusk until dawn and often seen hunting along trails on the ground, even on rainy evenings. Found near the colonies of *Hemidactylus* only at the westernmost buildings of the resort, 285m from the closest observed *Hemidactylus*, but the 2 species have never been seen in association.

Hemidactylus frenatus Duméril & Bibron, 1836. A common waif species found throughout much of the tropical and subtropical world. On Fitzroy Island this species is found among the resort's buildings and adjacent areas at lower elevations and the forest up to about 150m elevations. They are active on walls and ceilings of buildings and hunt on the ground further afield. Geckos crossing the road on rainy evenings, though rarely seen, resemble frogs, making short quick hopping movements. The senior author first noticed this behaviour when he stopped his vehicle to photograph what he believed was his first record for an amphibian on the island. This hopping behaviour, apparently not recorded elsewhere, was consistent when geckos were observed on rainy nights, but not seen when the lizards were not actually in the rain. They are entirely absent from the ranger base and lighthouse area. Toes elongated, oval, with 4 pairs of distinctly divided subdigital lamellae under the fourth toe. First digit tiny, with a feeble claw. Rostral large, broader than high. Dorsals granular, intermixed with small conical scales. Unbroken tail slightly depressed, with protruding soft spines that form annulations. Colour grayish to pink above, with marbled pattern of faint darker dorsolateral stripes in which are lighter spots. SVL 49-51mm; tail 62-65mm.

Apparently parthenogenic, only egg-bearing females observed. Egg laying and hatching occurring in June and July. Active from dusk until midnight and may be seen hunting along the road to the ranger's base up to an elevation of about 80m. Unlike *Gehyra* this species is generally not active on rainy evenings. If already active, the geckos immediately seek cover when rain starts. On cooler or overcast days these geckos will take advantage of midday sun to bask on tree trunks. When so basking they are more wary and do not allow an observer to approach as closely as at night. This species and *Gehyra* are active at much lower temperatures than the other island reptiles, observed at a low of 17°C.

Nactus cheverti (Boulenger, 1885). This is a padless, primarily ground-dwelling gecko with an elongated body and tail, pebbled skin and extremely thin, clawed digits. Found widely on the island in most localities and elevations except in shrub heath, under debris, rocks and fallen logs. May climb on shrubs and bases of trees, but primarily a ground dweller. Body dark brown with scattered tiny white specks. Coloration varies with exposure to light or temperature and may be light brown in the evening. The head may be pale yellow if the lizard is exposed during the day (Couper et al., 2000; Sprackland, 2000, 2001a, 2001b). Unbroken tail longer than SVL. SVL 41-50mm; tail 58-63mm. Once included as *Nactus pelagicus* but revised by Zug (1997).

Egg laying is in late July-August. Active at night among plants and debris, but rarely in the open. If crossing a path they make a sudden dash to cover the open distance and then hide in the foliage. Most common in late June-early August.

SCINCIDAE.

Carlia laevis (Oudemans, 1894). This species was the only reptile recorded for Fitzroy Island in print prior to 1999 (Macleay, 1878). The lizard is widespread in all areas that provide leaf litter, but because the lizards tend to forage under the leaves they are seldom seen. On Fitzroy Island, the heads of both sexes and all age groups are generally reddish brown, contrasting with the dull gray-brown body. Males have bright reddish tails. Body generally a flat brown, not shiny and without markings. SVL 35-39mm.

Diurnal, found in leaf litter in dappled sunlight. Moves in short bursts. Pairs and trios often seen foraging together. Males are territorial and aggressively chase other males away, but tolerate females and juveniles. Often found in association with *Carlia longipes*. The foraging *Carlia* may climb over and even bask upon a *Carlia* without eliciting a response from the larger skink. Feeds

on small insects including black ants, small beetles and bees. Skinks may take position outside a bee or ant nest and feed upon insects as they emerge. Also seen to attack tiny bits of dry leaves dangling and moving in the wind. Distinguished from *Saproscincus* in having reddish head and brown body. Though sympatric with the higher elevation *Saproscincus*, the microhabitat usage is distinct: the latter forages through grasses and over logs, while *Carlia* never moves away from leaf litter. Not found above about 140m.

Carlia longipes (Macleay, 1877). Extremely common and widespread, characterized by its tetradactyl front limbs, white-flecked black shoulder markings and reddish brown to bright red flanks. Observed at all localities and elevations on the island. Dorsal scales smooth and shiny. Body brown or bronze dorsally, with or without very tiny white speckling. Black mark, with tiny white flecks, extends from behind ear to shoulder. Red marking meets black flash and extends to mid body or groin; much more pronounced during breeding season. SVL 55-65mm.

Mating takes place in September-October and young emerge in May-June. Active all day once temperatures exceed 21°C; not found when wind is strong. They run across open spaces in 3-4m spurts, after each of which they often wriggle the tail and then dash again. This species is often found in association with *Carlia laevis* and may be oblivious to the smaller lizards. On several occassions the senior author has witnessed *Carlia* closely approach and even climb upon *Carlia* without any response from the latter.

QPWS (2001) recorded *Carlia storri* on the island, but our surveys did not.

Cryptoblepharus litoralis (Mertens, 1958). Small, flattened, with round, lidless eyes. Similar to *Cryptoblepharus virgatus* from which it differs in having a pale yellowish (vs. orange) head, no black dorsolateral stripes and slightly larger SVL (50-55mm vs 36-42mm).

A large colony lives among the large rounded boulders adjacent to Nudey Beach, where they occupy positions near the splash line with the sea. They forage along rocks and the beach, but rarely enter the water. They are sympatric with both *C. virgatus* and the larger *Eulamprus brachysoma*, but each species stays in exclusive abutting territories: *Eulamprus* on higher rocks, *C. virgatus* on rocks near the tree line and away from the water.

Cryptoblepharus virgatus (Garman, 1901). Lacking movable eyelids, it is widely distributed but highly secretive. The body is strongly depressed, with a pointed head. Limbs large and overlap when adpressed. Dorsum dark brown with two cream-coloured dorsolateral stripes from eyes to hips. Tail with characteristic zigzag pattern from hips to about halfway down its length.

An extremely wary species found across the island at all elevations in winter, but restricted to cooler locations in the rainforest during summer. Found mainly on boulders and tree limbs, basking in bright sun. They will climb tall trees in search of insect prey. The extremely thin body casts almost no shadow even in very bright sunlight, helping the lizard remain inconspicuous on exposed boulder surfaces. SVL 38-40mm; tail 50-55mm. Young appear in July and early August.

Egernia frerei Günther, 1897. Fitzroy Island's second largest lizard, the major skink is found primarily around the resort and along boulders on the walking paths on the western half of the island. Not yet observed on the ranger's road or the eastern portion of the island, or at elevations above 180m. A large (SVL 180-195mm), robust, smooth-scaled lizard with strong but widely separated limbs. It is more often heard than seen as it dashes through leaf litter to find shelter. Body light brown with faint darker dorsolateral stripes extending from the ear along the length of the tail. Ventrally cream, but some individuals have yellow.

Mating occurs in October-November, at which time the lizards loose much of their shyness of people, allowing closer approach than at other times. Active on warm days once temperature exceeds 24°C. Often found inside guest rooms at the resort.

Eulamprus brachysoma (Lönnberg & Andersson, 1915). Also widespread across the entire island, this black and gold marbled skink is also found in a variety of habitats, from rainforest, beach edges, heath and open areas around the ranger's base. Until recently, *E. brachysoma* was considered a subspecies of *E. tenuis*. Body elongate, with acute head. Scales smooth and shiny. Dorsal colouring black mottled with gold and lips conspicuously barred with pale gray and white. Tail longer than SVL, cylindrical. SVL 67-82mm; tail 84-90mm.

This is a viviparous skink and juveniles appear in June and July. This is a very alert species quick to take shelter if approached. They are terrestrial, seen around boulders, fallen trees, in rocks, in gardens, on stairs and tree trunks, but also

regularly enter buildings, where they may take residence within walls and under furniture. The largest observed colony, numbering 31 specimens ranging from subadults to adults, lives among the huge boulders on the farthest northwestern tip of the island, at the northern limit of Nudey Beach. Individual lizards were identifiable by a combination of a) size class (juvenile, subadult, adult), b) features of scale damage (most had scars or missing scales that were distinct), c) condition of tail (few had fully intact, original tails) and d) sex (based on lateral colour). At high tide there are two crevices that fill with seawater and in which the skinks swim and forage for food, capturing insects that have fallen into the water.

Glaphyromorphus crassicaudus (Duméril & Bibron, 1851). The QPWS have documented *Glaphyromorphus cracens* from the island, but our surveys failed to observe this species. We include it because a voucher specimen has been obtained. The specimen was reclassified when registered in the Queensland Museum collection as *G. crassicaudus* (Patrick Couper, pers. comm.).

Glaphyromorphus fuscicaudis (Greer, 1979). A single specimen was observed at the eastern edge of the campground, adjacent to the prawn hatchery, on 22 June 2003. Body cylindrical, robust, extremely smooth and shiny. Parietals long, in contact posteriorly. A single loreal. Lower eyelid moveable, opaque. Nasals undivided, supranasals absent. Two large prefrontals, barely in contact. Six supralabials, the fourth and fifth in contact with the eye. Five infralabials. Postmental in contact with first and second infralabials. Lower jaw countersunken compared to upper jaw. Four supraoculars. No ear lobules. Ear almost as large as eye, round. Adpressed limbs do not meet, separated by less than the length of the front limb. Pentadactyl, with 18 lamellae under fourth toe. Lower limbs pale pink. Dark brown above, with immaculate head. No dark lateral stripe. Neck and flanks brown with small darker brown flecks. Head chocolate reddish-brown. Ventrally cream, pinkish under tail. The tail was lost and being regenerated. SVL 85mm; right rear leg 25mm.

Glaphyromorphus nigricaudis (Greer, 1979). A single specimen of this area endemic was collected in the living room of the ranger's house on the evening of 23 June 2003. Similar to previous species except as follows: Ear opening oval. Snout not as attenuated or depressed. Head brown above, with no trace of reddish. Seven supralabials, fifth and sixth in contact with the eye. Postmentals contact first and second infralabials. Prefrontals in broad contact. Postfrontal not in contact with first preocular. Adpressed limbs meet. Golden brown dorsally with scattered light spots. Neck and sides with irregular, broken black band that extends to groin. Lips light with pale gray bars. Limbs brown with darker reticulation. Belly pale yellow. Sixty scales from parietal to hip. SVL 80mm. Right rear leg 19mm.

Saproscincus basiliscus (Ingram & Rawlinson, 1981). Another small skink with very similar habits to *Carlia laevis*, but almost always solitary when active. Found primarily in open grassy areas near the ranger's base and in heath above 100m elevation, but differs from *Carlia* in avoiding leaf litter and in being far less common. Body shiny, with comparatively large scales (larger than in *Carlia*), a gray-blue sheen and rounded (vs pointed) snout as seen in profile. SVL 36-40mm.

An active forager that is most likely to be seen in the lawn grass around the ranger base, where it will climb felled trees and low concrete structures to bask. Sympatric with *Carlia* around the ranger base, but persists to the eastern slope of the summit (269m).

VARANIDAE.

Varanus panoptes Storr, 1980. The Argus monitor, growing to SVL 660mm, is the largest lizard on the island and one of the top predators. A large group is present on Little Fitzroy Island and specimens have been observed on Fitzroy near the resort, along the road to the ranger base (in scrub, not rainforest sites) and at the ranger base, all north-facing localities. Monitors are basking in the early morning and late afternoon, at which times they are most likely to be observed. By day they forage widely. Pattern variable, ranging from dark brown with large pale spots to dark brown with tiny spots. The tail is patterned like the dorsum and is conspicuously compressed laterally.

Like other monitors, this is a heat-loving animal that is not seen if temperatures are below 30°C. It is also going to remain concealed if winds exceed 5 knots.

PYTHONIDAE.

Morelia spilota (Lacépède, 1804). Carpet pythons are common, with numerous sightings being recorded. Our survey found shed skin and a skeleton (Sprackland, 2000, 2001a), while QPWS obtained a photograph (QPWS, 2001). Prawn hatchery staff relate that the snakes are

commonly seen after dusk near the hatchery. On 20 July 2003 a large specimen was observed when it fell out of a tree while in the process of eating a bat (*Pteropus conspicillatus*).

COLUBRIDAE.

Boiga irregularis (Merrem, 1802). A single adult was observed crossing the access road at 'Near Death Curve' at 2127hr on 26 July. Despite the day having been cool (22°C) and windy (23-28 knots), the evening was calm and the snake slowly crossed the road into the northeastern rainforest. Length was approximately 1.2m and colour deep brown with very faint darker cross-bands. According to staff at the prawn hatchery, this species is common across the island.

Dendrelaphis calligastra (Günther, 1867). A single specimen was collected in 2000 and is now in the Queensland Museum. It is reportedly common around the resort buildings during the day and is frequently encountered when palm trees are trimmed of their coconuts, but they are difficult to observe and our survey did not encounter the snake.

MAMMALS OBSERVED

MACROPODIDAE.

Macropus giganteus Shaw, 1790. A single adult kangaroo was observed and has long been the subject of sporadic reports by visitors and rangers on the island. Our survey found fresh footprints and scat with a 40mm maximum width in 2000 and 2003. A photograph was obtained of the animal on a path to the SE of the ranger base in 2003. The exact taxonomy is unsure and the animal may be a pale *Macropus agilis* (Weston & Krockenberger, pers. comm.). Spoor collected by Weston & Sambono in 2000 were identified as '*Macropus agilis* and *M. gigantens*' by Barbara Triggs (Weston, pers. comm.), but the comment may have been a typographical error ('and' in place of 'or'). We cannot rule out the possibility that both species occur in the heavily forested and largely impenetrable and unexplored central valleys on Fitzroy Island, though only one species was observed.

PTEROPODIDAE.

Pteropus conspicillatus Gould, 1850. Spectacled flying foxes are common on Fitzroy Island, with several roosting locations atop the tallest trees. We have observed the roosts above the water tanks SE of the resort bunkhouses and 50m into the Secret Garden path at the resort's SE. The bats become active around dusk and feed on a variety of fruits and flowers. This species, first reported from the island by Thomas Henry Huxley in 1845 when he was the assistant surgeon on Capt. Owen Stanley's HMS *Rattlesnake*, regularly flies across the channel to adjacent Cape Grafton.

HIPPOSIDERIDAE.

Hipposideros ater Templeton, 1848. This 40-45mm bat is the most common mammal on Fitzroy Island and is regularly observed at all elevations and in all habitats from shortly before dusk until about midnight. They are most typically encountered near lights, where they strafe footpaths and roads for insect prey. They are fast and remarkably agile fliers that sometimes stray into buildings. We observed one bat fly back and forth in the upper confines of a 1m wide closet for 15 minutes without hitting a wall.

DISCUSSION

Our survey spanned 4 months, during most of which we could only observe and photograph animals in situ. We recorded 17 species of reptiles and 3 mammals, representing 18 genera. Though we surveyed the island at different times of the year, we accept that some taxa may have eluded us due to seasonal or collecting limitations. Certainly the difficulty of the terrain makes likelihood of encountering some potential inhabitants, such as *Antaresia* as well as the confirmed *Saproscincus* and *Boiga*, a problem for surveyors. However, we recorded 4 species from Fitzroy Island for the first time during 2003, including *Glaphyromorphus fuscicandis*, *G. nigricandis* and *Hipposideros ater*.

A short survey conducted 2-8 December 2000 by Nigel Weston & Joe Sambono (2001) included *Egernia frerei*, *Morelia spilota* and *Stegonotus cucullatus* as observed species and they reportedly lodged several lizard taxa with the Queensland Museum (Table 2). From their survey, only *Lepidodactylus lugubris*, *Stegonotus cucullatus* and *Carlia* cf. *rostralis* were not seen by our surveys and it is possible the latter was misidentified (Goodman, pers. comm.).

In October 2001 the Queensland Parks and Wildlife Service conducted a staff workshop on Fitzroy Island and employed a variety of sampling techniques (observation, pitfall and Elliot trapping) to record 72 observations (Freeman, pers. comm.; QPWS, 2001). The collection differs from ours only in recording *Glaphyromorphus cracens* (in error; see Table 1) and *Carlia storri*. Interestingly, none of the five surveys recorded a single frog, though a former

TABLE 1. Reptile and mammal species observed by the VMNH surveys of 1999, 2000 and 2003, exclusive of the birds (for which see Malone, 2001), or for which a voucher specimen exists (*). 1. Initially identified as *G. cracens* in an unpublished QPWS report, but diagnosed and catalogued as *G. crassicaudus* by the Queensland Museum, where the single specimen has been deposited (Patrick Couper, pers. comm.).

Reptilia	*Northern Tree Dtella, *Gehyra dubia* Asiatic House Gecko, *Hemidactylus frenatus* *Yellow-headed Ground Gecko, *Nactus cheverti* Red-sided Skink, *Carlia longipes* Litoral Skink, *Cryptoblepharus litoralis* Snake-eyed Tree Skink, *Cryptoblepharus virgatus* Major Skink, *Egernia frerei* *Marbled Skink, *Eulamprus brachysoma* *Short-legged Ground Skink, *Glaphyromorphus crassicaudus*[1] Bronze Ground Skink, *Glaphyromorphus fuscicaudis* Red-headed Ground Skink, *Glaphyromorphus nigricaudis* *Leaf-litter Skink, *Carlia laevis* Shade Skink, *Saproscincus basiliscus* Argus Monitor, *Varanus panoptes* Carpet Python, *Morelia spilota* Brown Tree Snake, *Boiga irregularis* *Green Tree Snake, *Dendrelaphis calligastra*
Mammalia	Gray Kangaroo, *Macropus giganteus* Dusky Leaf-nosed Bat, *Hipposideros ater* Spectacled Flying Fox, *Pteropus conspicillatus*

ranger claims he observed two species of *Litoria* on the island. His notes included *Antaresia maculosa*, '*Morelia kinghorni*', *Liasis mackloti* and the frogs *Litoria caerulea* and *L. infrafrenata*, though we found no evidence for these species and these reports are unconfirmed by photographs or voucher specimens (QPWS, 2001).

The combined surveys sampled island fauna in the months of June, July, August, October (twice) and December. A significant limitation of the sampling already performed is that it represents areas on only about 12-15% of the island's surface. Much of the south and central areas have yet to be explored adequately, if at all. It is still an open question, for example, whether or not a standing pond and surrounding grassland exists in the steep valley about 800m SSE of the ranger base. If present (pond side grasses replace shrubby heath as observed from summit vantage points), the habitat could harbor frogs, additional lizards and perhaps be home to the elusive macropods. Kangaroos were largely removed from the island around 1985-1986 because they were a perceived threat to tourists at the new resort. Spoor, footprints, videotape and a photograph have all been obtained of at least one animal (all but the video by the VMNH survey in

TABLE 2. Herpetological and mammal species reported for Fitzroy Island in unpublished reports or for which only trace evidence (*) was observed by the VMNH surveys. a = Weston & Sambono (2001); b = QPWS unpublished report (2001); c = QPWS anecdotal reports from rangers (pers. comm.), probably in error. 1. Possibly a misidentified *Carlia longipes*.

Mammalia	a. Native Rat, *Melomys burtoni*
Reptilia	a. Mourning Gecko, *Lepidodactylus lugubris* a. Skink, *Carlia* cf. *rostralis*[1] a, b. Skink, *Carlia storri* c. Cogger's Skink, *Lampropholis coggeri* c. Spotted Python, *Antaresia maculosa* c. Amethystine Python, *Morelia amethistina* c. Water Python, *Liasis mackloti* a, b, c, * Slaty-gray Snake, *Stegonotus cucullatus*
Amphibia	c. White's Tree Frog, *Litoria caerulea* c. White-lipped Tree Frog, *Litoria infrafrenata*

2003), though its home area and status as a loner or part of a colony remain unknown.

Though we did not find evidence of *Melomys burtoni*, Weston & Sambono collected a lactating female in heath habitat in 2000 (Weston, pers. comm.).

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LITERATURE CITED

COGGER, H.G. 1999. Reptiles and amphibians of Australia. (Ralph Curtis Books: Florida).

COUPER, P, COVACEVICH, J., JANETZKI, H.& MCDONALD, K. 2000. Lizards. In, Wildlife of tropical north Queensland. (Queensland Museum: Brisbane).

Le CUSSAN, J. 1997. Fitzroy Island National Park; description of vegetation with recommendations for fire management. (QPWS: Brisbane).

MACLEAY, W. 1878. The lizards of the "Chevert" expedition (part 2). Proceedings of the Linnean Society of New South Wales 2: 97-104.

MALONE, L. 2001. Checklist of the birds of Fitzroy Island. Zoologica Nova at www.curator.org.

QUEENSLAND PARKS AND WILDLIFE SERVICE 2001. Herpetological records for Fitzroy Island National Park. (Unpubl.).

SPRACKLAND, R.G. 2000. The reptiles of Fitzroy Island. Virtual Museum of Natural History Expedition Report 1 at www.curator.org.

2001a. Lizards in paradise. Reptiles 9(9): 11-16.

2001b. Reptiles of Fitzroy Island. Reptilia 15: 56-60.

2001c. The reptiles of Fitzroy Island. Virtual Museum of Natural History Expedition Report 2 at www.curator.org.

SWAN, G. 1995. A photographic guide to snakes and other reptiles of Australia. (Ralph Curtis Books: Florida).

WESTON, N. & SAMBONO, J. 2001. Fitzroy sampling notes. (QPWS: Brisbane) (Unpubl.).

ZUG, G. 1997. Australian populations of the *Nactus pelagicus* complex (Reptilia: Gekkonidae). Memoirs of the Queensland Museum 42(2): 613-626.

NEW DISTRIBUTION AND HABITAT DATA FOR THE CARPENTARIAN FALSE ANTECHINUS (*PSEUDANTECHINUS MIMULUS*). *Memoirs of the Queensland Museum 49(2): 740. 2004:-* *Pseudantechinus mimulus* was first described from a specimen collected from Alexandria (19°03'S, 136°42'E) in the Northern Territory (Thomas, 1906). It was later synonymised by Mahoney & Ride (1988) with *P. macdonnellensis*. However, 3 additional specimens collected in 1991 from the North Island of the Sir Edward Pellew Island Group in the Northern Territory were used to redescribe the species (Kitchener, 1991). Further surveys of the Edward Pellew Island Group collected animals from the Central and South West Islands (Johnson & Kerle, 1991).

The animal was not known from Queensland until 1997 when 3 individuals of *P. mimulus* were collected east of Mt Isa (T. Griffiths unpubl. data, 1997). In May 2002 we collected only the fourth animal known from Queensland. The animal was captured during a routine baseline survey 140km SE of Mt Isa (21° 34' S and 140° 29' E) in the Selwyn Ranges and was lodge with the Queensland Museum (QMJM15044).

The animal was captured on a standard small mammal bait mix in a Type A Elliot trap on the western side of the rocky slope beneath a rocky outcrop. The capture site was dominated by an understorey of spinifex grasses (*Triodia molesta* and *T. longiceps*) in a region typified by an open woodland of Snappy Gum (*Eucalyptus leucophloia*).

The geology at the capture site was a variably brecciated calc-silicate unit that consisted of coarse (approximately 2mm) particles that readily crumbled under pressure. The capture site was adjacent to disturbed land associated with the construction of a new road. Furthermore, a recent fire had passed within close proximity, but had not burnt vegetation in the immediate area.

Little additional habitat data is available on *P. mimulus*. The collection location for the holotype, Alexandria Station, largely encompasses tussock grassland on blacksoil plains. However, the area historically referred to as Alexandria is considerably larger than currently recognised and the precise location where the holotype was collected cannot be accurately determined (Fisher et al., 2000).

Habitat data from individuals collected in Edward Pellew Island Group suggest that *P. mimulus* is predominantly a sandstone species. In this respect, the *P. mimulus* habitat selection is similar to many of its congenitors which have also been found predominantly on sandstone (Fisher et al., 2000; Woolley, 1995a, 1995b). Upland rocky ranges that contain sandstone extend from the Edward Pellew Island group SE to the Selwyn Ranges (Fisher et al., 2000).

Pseudantechinus mimulus is recognised as Vulnerable nationally (Maxwell et al., 1996) but does not have a published status in Queensland. Systematic surveys of the Mt Isa area are required to fully determine the status of this species.

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Literature Cited

FISHER, A., WOINARSKI, J.C.Z., CHURCHILL, S., TRAINOR, C., GRIFFITHS, A.D., PALMER, C. & COOPER, N. 2000. Distribution of the rock-dwelling dasyurids *Pseudantechinus bilarni* and *P. ningbing* in the Northern Territory. Northern Territory Naturalist 16: 1-13.

JOHNSON, K. A. & KERLE, J. A. (eds) 1991. Flora and vertebrate fauna of the Sir Edward Pellew Group of Islands, Northern Territory. (Conservation Commission of the Northern Territory: Alice Springs).

KITCHENER, D. J. 1991. *Pseudantechinus mimulus* (Thomas, 1906) (Marsupialia, Dasyuridae): rediscovery and redescription. Records of the Western Australian Museum 15: 191-202.

MAHONEY, J. A. & RIDE, W. D. L. 1988. Dasyuridae. Pp 14-33. In Zoological catalogue of Australia. Vol 5. Mammalia (Australian Government Publication service: Canberra).

MAXWELL, S., BURBIDGE, A.A. & MORRIS, K. (eds) 1996. The 1996 action plan for Australian marsupials and monotremes. (Wildlife Australia: Canberra).

THOMAS, O. 1906. On mammals from northern Australia presented to the National Museum by Sir Wm. Ingram, Bt., and the Hon. John Forrest. Proceedings of the Zoological Society of London 2: 536-543.

WOOLLEY, P.A. 1995a. Fat-tailed Pseudantechinus: *Pseudantechinus macdonnellensis*. Pp. 76-77. In Strahn, R. (ed). The mammals of Australia. (Reed New Holland: Sydney).

1995b. Woolly's Pseudantechinus: *Pseudantechinus woolleyae*. Pp. 80-81. In Strahn, R. (ed). The mammals of Australia. (Reed New Holland: Sydney).

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A NEW FAMILY AND GENUS OF PHREATOICIDEA (CRUSTACEA: ISOPODA) FROM ARTESIAN SPRINGS IN SOUTHWESTERN QUEENSLAND, AUSTRALIA

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Two new species of phreatoicidean isopods from artesian springs in southwestern Queensland are described. These taxa have been shown to form a clade that is distinct from all other taxa in the suborder. Therefore, a new genus, *Ponderella*, and a new family, Ponderellidae, are established for this clade. These two epigean species share many features in common with the hypogean family Hypsimetopidae but lack their derived features, such as elongate bodies or curved claw-like uropodal endopods. Both new species share an enlarged fourth article of the antennula, a synapomorphy that occurs in no other phreatoicidean. Their pleotelsons are also distinctive in having relatively unelaborated posterior margins that are indented at the apices. The two species differ in several morphological traits that vary at the generic level or higher in other families of the Phreatoicidea: size of the lacinia mobilis on the right mandible; distinctive modifications of the male pereopod IV in one of the species; presence or absence of propodal articular plates on the posterior percopods; presence or absence of the pleopodal lateral epipods; and shape of the pleotelson in lateral view. These species occur sympatrically in two adjacent localities in the Eulo mound springs supergroup. Because of their restricted distribution in habitats that lack environmental protection, these species are potentially endangered. ❑ *Phreatoicidea, Isopoda, artesian springs, Queensland, new taxa.*

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Species of phreatoicidean isopods occur throughout Australia (Nicholls, 1943, 1944; Wilson & Keable, 1999, 2001, 2002a,b). Until recently, Queensland was the only state in which phreatoicideans had not been recorded, despite this state having many diverse, potentially suitable habitats. An extended field trip in 1998 by the first author and colleagues along the coastal ranges of Queensland found no phreatoicideans. Recent investigations by Dr Winston Ponder and associates discovered two new phreatoicidean isopod species from artesian springs at Bundoona Homestead and the Eulo Township of southwest Queensland. In addition to the new phreatoicidean isopod species, these sites had 5 new species of hydrobiid gastropods of the genus *Jardinella* (W. Ponder, pers. comm.), with other possible endemics being at least one species of amphipod and a leech. These artesian springs are associated with the Great Artesian Basin, the majority of which is in Queensland. These springs, located in otherwise arid regions, provide a unique habitat for a variety of endemic invertebrates (Ponder, 1986; 2004). Notably, hydrobiid snails have radiated in the Queensland springs (Ponder & Clark 1990).

An initial hypothesis of relationships of the phreatoicidean species, based on the habitat where they occur, suggested that they would be related to *Phreatomerus* Sheppard, 1927, found in artesian springs of South Australia. Further study and a phylogenetic analysis (Wilson & Edgecombe, 2003; available at available at TreeBase, http://www.treebase.org, study accession no. S797, matrix accession no. M1262; reported as 'Qld n sp.1' & 'Qld n sp.2') demonstrated that the unique combination of features in these two species prevents their classification in an existing family. They are unlike any other phreatoicidean and are assigned here to a new genus, *Ponderella* and a new family Ponderellidae.

MATERIALS AND METHODS

Specimens were fixed in either sodium bicarbonate neutralised 10% formalin solution or 95% ethanol. Preparation of specimens for scanning electron microscopy (SEM) included dissection and isolation of individual limbs, ultrasonic cleaning and CO_2 critical point drying. Images were obtained using a Leo 435VP SEM equipped with a Robinson backscatter detector, and then saved as digital TIF files. The images

were placed into digital image figures with the background removed. Pleopod and holotype figures were prepared using a camera lucida and light microscopy, inked, scanned and saved as TIF files. Descriptions were prepared using DELTA (Dallwitz, 1980; Dallwitz, et al., 2000a,b) as employed by Wilson & Keable (1999, 2001, 2002a,b).

ABBREVIATIONS. AM, Australian Museum, Sydney; QM, Queensland Museum; bl, body length; GPS, global positioning satellite fix; ind., individuals, specimen or specimens.

SYSTEMATICS

PONDERELLIDAE fam. nov.

TYPE GENUS. *Ponderella* gen. nov., family monotypic.

DIAGNOSIS. Head with small eyes (diameter less than antennal base), not protruding; antennal notch absent. Pleonites in lateral view much deeper than pereonites, pleurae large, basal region of pleopods not visible, pleonite 1 pleura distinctly shallower than those of pleonites 2-5. Pleotelson postanal ventral surface present, unelaborated; posterior apex indented in dorsal view, free (not strongly reflexed or flattened against dorsal surface); posterolateral margin projecting in lateral view but continuous with apex; ventral margin anterior to uropods narrow (less than width of uropodal insertion). Paragnaths lateral lobe margin densely setulate in compact distomedial region, sparsely setulate distolaterally and medially. Antennula article 4 longer than article 3; penultimate article elongate, tubular, longer than ante-penultimate article; terminal article tiny with single aesthetasc. Mandible incisor processes thin in medial view, width near thickness, resembling dentate spines; right lacinia mobilis distinct, inserting distally at base of projecting spine row with single dentate plate (anterior surface of plate smooth); spine row on projecting ridge between incisor and molar, basal insertions in line between incisor and molar processes. Pereopods V-VI basis dorsal margin angular in cross-section, not plate-like; VII basis dorsal margin with enlarged plate. Pleopods exopods II-V proximal article distolateral lobes subequal to or longer than distal article. Uropod protopod dorsomedial ridge not produced; rami distal tips rounded, cross-sectional shape flattened on dorsal surface only.

Ponderella gen. nov.

TYPE SPECIES. *Ponderella bundoona* sp. nov., here designated.

SPECIES INCLUDED. *Ponderella bundoona* sp. nov., *P. ecomanufactia* sp. nov.

ETYMOLOGY. *Ponderella* honours Winston F. Ponder's many contributions to our knowledge of Australia's freshwater biodiversity, especially his research on artesian springs that resulted in the discovery of these new species.

DESCRIPTION (MALES). *Head.* (Fig. 2A-B) Lateral profile of dorsal surface smoothly curved; width approximately 0.9 pereonite 1 width; surface smooth and shiny; tubercles absent; setae fine. Eyes fully sessile (i.e., not protruding); pigmentation dark. Cervical groove straight (weak). Mandibular notch present (weak). Clypeal notch present (weak). Frontal process above antennula absent. Mouthfield angling ventrally, mandibular insertion axis in lateral view nearly level, line projected anteriorly along mandibular insertion passing below base of antenna; adjacent to posterior margin of head and anterior margin of pereonite 1.

Pereon. (Fig. 1A) Width near head width; surface smooth; setae on dorsal surface scattered, fine. Pereonite 1 dorsal margin in lateral view shorter than on pereonite 2. Pereonites 2-7 in dorsal view wider than long. Coxal articulation of pereonites 2-4 fused, 5-7 free. Lateral tergal plates of pereonites 2-4 not extended over basis. Sternal processes absent. Typhlosole absent, gut round in cross-section; hindgut caecae absent.

Pleonites. (Fig. 1A) In dorsal view 2-4 respective lengths more than half the length of pleonite 5. Pleonite 5 dorsal median ridge absent.

Pleotelson. (Fig. 6E-F) Dorsal surface in lateral view evenly curving (curvature increasing at posterior margin), covered with abundant curled simple setae, median ridge and lateral ridges absent; ventral surface anterior to uropods strongly concave; with single row of simple robust setae; lateral uropodal ridge curving strongly and extending posteriorly from uropods on pleotelson margin, lacking setae.

Antennula. (Fig. 2A,D) Article 3 rudimentary second flagellum absent. Terminal article shorter than penultimate article. Penultimate article length not distinctly longer than other articles; width approximately subequal to ante-penultimate article width. Distal articles oval in cross-section.

Antenna (Fig. 2A-D) article 6 shorter than articles 4 and 5 combined. Flagellum proximal articles without dense cover of cuticular hairs.

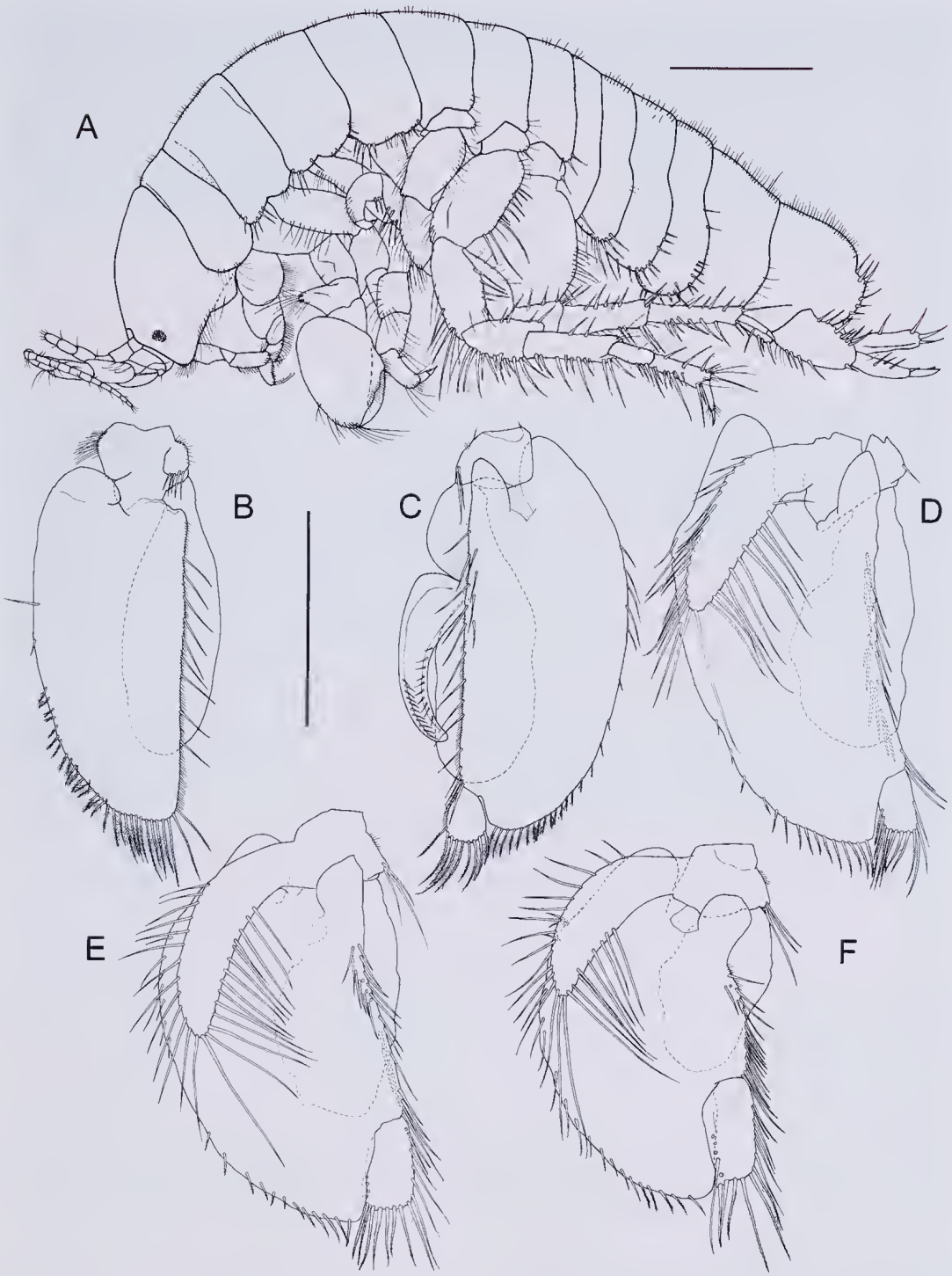

FIG. 1. *Ponderella bundoona* gen. et sp. nov. A, lateral view, holotype ♂, QM W26732; scale bar 2mm. B-F, pleopods I-V, ventral view, ♂, AM P64023; scale bar 1mm.

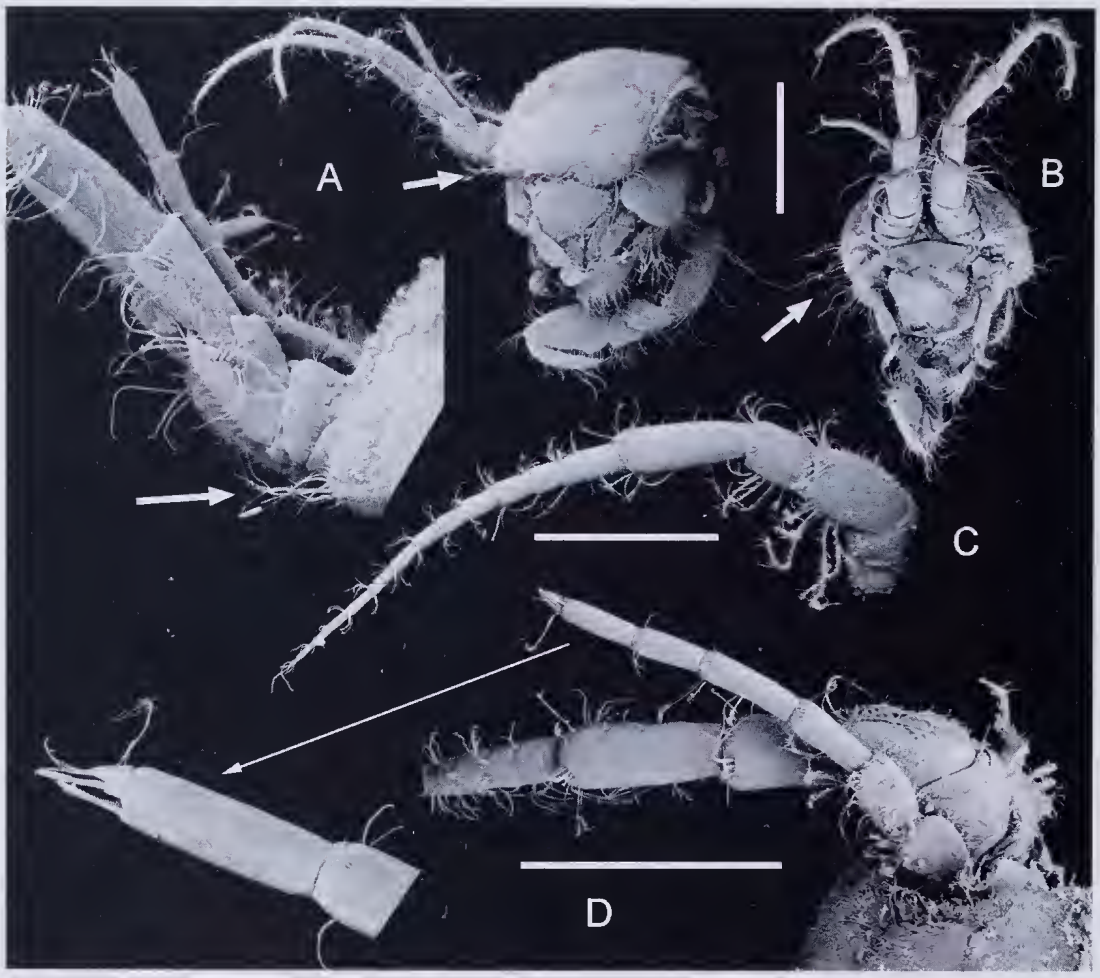

FIG. 2. *Ponderella bundoona* gen. et sp. nov. A-B, head and right pereopod I, left lateral and frontal views, with enlargement of antenna base and antennula, heavy arrow indicates setal fringe, ♀, AM P64022. C-D, antenna and antennula with enlargement of distal tip, ♂, AM P64020. Scale bars 0.5mm.

Mouthfield. (Fig. 2A-B) Clypeus consisting of broad bar rounded at mandibular fossae, deeper on left side; labrum ventrally semicircular in anterior view, deeper on right side, labrum dorsal margin approximately same width as clypeus.

Mandible. (Fig. 3) Palp article 1 easily visible; 2nd article longitudinal row of setae present, separate distal group of setae present; 3rd article without coarsely spinulate setae. Incisor processes thin, resembling denticulate spines, width near thickness. Right incisor process with 4 cusps; left incisor with 3 cusps. Right lacinia mobilis well-separated and distinct from spine row. Left lacinia mobilis with 3 cusps. Spine rows with bifurcate spines, distal margin protruding in ventral view relative to proximal margin. Left spine row with first spine not separated from remaining spines. Molar process stout, heavily keratinised, wider than long; triturating surface heavily ridged, without teeth, spines absent.

Maxillula. (Fig. 4B) Medial lobe with 3 pappose setae; short weakly setulate seta on distal tip absent. Lateral lobe distal margin narrow, with 5 smooth robust setae, distal setal row with 4 robust setae; ventral face with 1 plumose seta, additional plumose seta among proximal distal robust setae.

Maxilla. (Fig. 4C) Medial lobe proximal portion distinctly angled to distal portion; proximal and distal setal rows continuous. Outer lateral lobe length subequal to inner lateral lobe, wider than inner lateral lobe, distal margin setal row with

FIG. 3. *Ponderella bundoona* gen. et sp. nov. A, right mandible, dorsal view and enlargement of incisor process and spine row, arrow indicates scale-like lacinia mobilis, ♂, AM P66836. B-D, left mandible, ♂, AM P 64028: B, dorsal view of distal tip; C, palp, posterior view; D, whole, medial and ventral view; E, enlargement of incisor process, lacinia mobilis and spine row, medial view. Scale bars 0.1mm.

two angles — transverse to lateral margin and oblique on medial margin.

Maxilliped. (Fig. 4D) Epipod distal tip truncate (linear across distal margin). Palp article 4 subcircular (length subequal to width).

Pereopods. (Fig. 1A) Coxae not projecting laterally. Pereopod I (Fig. 5A-B) subchelate. Dactylus dorsal margin dense group of elongate setae absent; ventral margin proximal projection absent; ventrodistal margin smooth; with 1 distal accessory claw; distal accessory spines absent. Propodus dorsal margin setae in several groups between proximal and distal margin; proximal region recurved and protruding to distodorsal margin of carpus. Propodal palm (proximal to medial spine) concave; with 1 proximal simple spine (rounded), with 1 median simple spine, with several small distal simple spines, composite spines absent; cuticular fringe weakly developed; medial rugose cuticular pad absent; stout denticulate setae absent; stout robust simple setae absent; elongate broad-based setae absent. Merus distodorsal margin in cross-section shelf-like and U-shaped (in cross section), with numerous elongate simple setae. Pereopods II-III (Fig. 5F) dactylus shorter than propodus, lateral spine absent; propodus articular plate absent; basis dorsal ridge in cross-section angular but not forming distinct plate, dorsal ridge proximal knob absent. Pereopod IV (Fig. 5E) prehensile in male, subchelate with major hinges on dactylus and propodus, limb simple in female; dactylus longer than propodal palm; propodus with multiple broad based setae on ventral margin, some distinctly larger than others, articular plate on posterior side of limb absent in female; carpus of male with single setal row; basis dorsal ridge in cross-section angular but not forming distinct plate. Pereopods V-VII (Fig. 6A-C) basis lateral face central ridge absent, ventral ridge present (weak), setae absent; basis VII dorsal ridge distal margin rounded; ischium VII dorsal ridge flange absent.

Penes. (Fig. 6D) Curved posteriorly; extending past midline and onto pleonite 1; cuticle smooth, with setae on shaft; distally broadening, distal tip flattened.

Pleopods. (Fig. 1B-F) Lateral proximal lobes on exopods I-V, medial proximal lobes on exopods II-V. Endopods unilobed; I-V without setae on margins. Protopods medial margins without coupling hooks, with minutely serrate setae; protopod I lateral epipod absent, protopod II lateral epipod absent. Pleopod I exopod broadest proximally, distal margin rounded, lateral margin rounded, medial margin straight - divergent from lateral margin proximally, dorsal surface lacking setae, ventral surface flat; protopod length subequal to that of other pleopods, width subequal length. Pleopod II endopod appendix masculina curved, distal tip extending beyond half length of endopod, not reaching distal margin of endopod; proximal half of shaft broadly concave in ventral cross-section, not forming tube; distal tip acutely rounded, distal tip margins smooth; with multiple setae on margin, occurring laterally and medially. Pleopod II endopod distal margin rounded; exopod distal segment longer than wide.

Uropod. (Fig. 6E,G) Protopod extending posteriorly subequal to pleotelson apex; dorsomedial ridge in dorsal view parallel to ventral margin, setae on margin robust and simple; dorsolateral margin setae robust and simple; distomedial margin without spinose setae; ventral ridge without rows of long laterally projecting setae. Endopod subequal-longer than exopod, straight-curving dorsally; dorsal margin robust setae along length; spine on dorsal margin absent; ventral margin convex-straight proximally. Exopod shorter than pleotelson; exopod dorsal margin with multiple robust setae.

DISCUSSION. Species of *Ponderella* gen. nov. possess both unique synapomorphies and a combination of other characters that contributed to their isolated position in phylogenetic analyses of the Phreatoicidea (see Wilson & Edgecombe, 2003). The long fourth article of the antennula (longer than article 3; Figs 2D, 8B) is a putative synapomorphy separating *Ponderella bundoona* n.sp. and *P. ecomanufactia* n.sp. from all other phreatoicidean genera. While article 4 can be large in some hypsimetopid species, being subequal to the next distal article, it is never longer than article 3. Additionally, the paragnaths, a feature not often used in isopod systematics, are contracted and have relatively thick (in a dorsoventral direction) distomedial brushes of setae in *Ponderella* (Fig. 4A). Most other phreatoicideans have a thin, dense row of setae that curves around the margin from the inner medial edge to the lateral edge (e.g., Wilson & Keable, 2002b: fig. 4A). Also in most other taxa, the lengths of the paragnath setae taper to shorter lengths medially, and in *Ponderella* these setae are all near the same length. In *Ponderella*, pleopod exopods II-V have the proximal article distolateral lobe (Figs 1B-F) subequal or longer

FIG. 4. *Ponderella bundoona* gen. et sp. nov. A-B, ♂, AM P64020; C-D, ♂, AM P 64028. A, paragnaths, ventral view. B, maxillula, ventral view, with enlargement of inner lobe tip and medial view of outer lobe robust setae. C, maxilla, ventral and dorsal views. D, maxilliped, ventral view, with enlargement of endite, medial oblique view. Scale bars 0.1mm.

FIG. 5. *Ponderella bundoona* gen. et sp. nov. A-B, left pereopod I, lateral view, with enlargement of palm medial view; E-F, pereopods IV (right) and II (left), lateral views, ♂, AM P 64028. C-D, pereopod I (distal articles only) and IV, left lateral views, ♀, AM P64022. Scale bars 0.1mm.

FIG. 6. *Ponderella bundoona* gen. et sp. nov. ♂, AM P 64028. A-C, pereopods V-VII, right lateral view, scale bar 0.5mm. D, penes, right side, anterior view. E, pleotelson and uropods; scale bar 0.5mm. F, pleotelson apex, ventral view. G, uropod protopod, ventral view of distal tip showing spinose setae. H, pleopod II appendix masculina, ventral view; scale bar 0.1mm.

than the distal article. This feature otherwise is only found in the hypsimetopid clade (i.e., *Hypsimetopus* Sayce, 1902; *Hyperoedesipus* Nicholls & Milner, 1923; *Nichollsia* Chopra and Tiwari, 1950; *Phreatoicoides* Sayce, 1900; *Pilbarophreatoicus* Knott & Halse, 1999). Also similar to some hypsimetopids, the mandibular right lacinia is a simple flat toothed plate and is unlike those of the phreatoicid or the amphisopid clades, where an additional anterior toothed lobe is present. The right lacinia of the phreatoicids differs further in being more spine-like and incorporated into the spine row. As in the hypsimetopids, phreatoicids, and the genera *Mesamphisopus* Nicholls, 1943 and *Crenisopus* Wilson and Keable, 1999, the antennula has a tiny distal article and an elongate penultimate article. In these latter taxa, the penultimate article is variously inflated, while it is thin and tubular in *Ponderella*. In all of these taxa mentioned, the tiny terminal article has only a single aesthetasc, evidence that it has not been fused with other articles. In contrast, the amphisopids (excluding *Mesamphisopus*) appear to have several terminal antennular articles that are fused because the last article has several distinct clusters of aesthetascs. The penultimate antennular article of amphisopids is not elongate nor does it consist of several fused articles.

Although sharing several features with the hypsimetopids as noted above, species of *Ponderella* lack many of their derived characters. The pleonites are not substantially modified, being deeper than the pereonites; the body is not thin and elongate; the pleotelson is deeper than long; eyes are present, although small; the pereopods are not attenuated in any way; the uropods lack specialisations such as medially curved claw-like endopods. This pattern in *Ponderella*, however, is plesiomorphic within the Phreatoicidea.

Other notable characters that indicate relationships of *Ponderella* species are found in the pereopods and the pleotelson. Although the basis dorsal margin on the posterior pereopods varies considerably among the phreatoicideans, *Ponderella* species are unique in lacking dorsal processes on the bases of pereopods V and VI, and having an enlarged dorsal plate on the basis of pereopod VII (Figs 6A-C). The rounded dorsal plate of the pereopod VII basis in *P. bundoona* n.sp. is similar to that occurring in *Phreatomerus* Sheppard, 1927 but this latter taxon also has large plates on pereopod bases V-VI. The position of posterior pereopods (V-VI) in preserved specimens of *Ponderella* suggest that these legs can rotate at the coxae well forward of a line perpendicular to the body axis, whereas they are held more posteriorly in most other phreatoicideans (except the semiterrestrial *Phreatoicopsis* Spencer & Hall, 1896).

The shape of the posterior margin of the pleotelson (fig.6E-F, 12A-B) is also distinctive in species of *Ponderella*, largely because it lacks substantial elaboration, such as posterolateral plates or lobes, or a reflexed posterior apex. Genera with a similar pleotelson include *Crenisopus*, *Mesamphisopus* and *Protamphisopus* Nicholls, 1943. In the first two of these taxa, the pleotelson lateral margins converge smoothly to a variously projecting posterior apex. *Ponderella* species differ because the pleotelson apex appears indented in dorsal view and the posterolateral margins project posteriorly beyond the apex. Other taxa that have unelaborated pleotelson margins (e.g., *Phreatoicopsis* or the hypsimetopids) differ because their anus is adjacent to the margin of the posterior apex; i.e., it has no postanal ventral surface. We are uncertain of the condition of the postanal surface in the fossil taxon *Protamphisopus* Nicholls, 1943, but this taxon lacks any of the pleotelson specialisations seen in the hypsimetopids (Wilson & Edgecombe, 2003), and thus is more similar to *Ponderella*. Consideration of potential outgroups and the observed basal phylogenetic position of *Crenisopus* and *Ponderella* suggests that this unelaborated form of the pleotelson may be plesiomorphic.

Although sympatric, each species of *Ponderella* is distinctive in features that are usually constant within a phreatoicidean genus. For example, pleopod III-V protopod lateral epipods are present in *Ponderella bundoona* and absent in *P. ecomanufactia*. The right lacinia is a large plate in *P. ecomanufactia*, but a small tooth at the base of the spine row in *P. bundoona*. The incisor process appears to be smaller and less projecting in *P. bundoona* than in *P. ecomanufactia* (compare Figs 3A and 9A). The antennae are different sizes, compared to the body length, being short in the more diminutive *P. bundoona* and elongate in *P. ecomanufactia*. The fourth pereopods are highly dimorphic in *P. ecomanufactia*, with an expanded plate on the carpus in the male, while the same limb of *P. bundoona* is not as robust. *Ponderella ecomanufactia* males have a propodal articular plate on pereopod IV (absent in females) while both sexes of *P. bundoona* lack the plate. Both

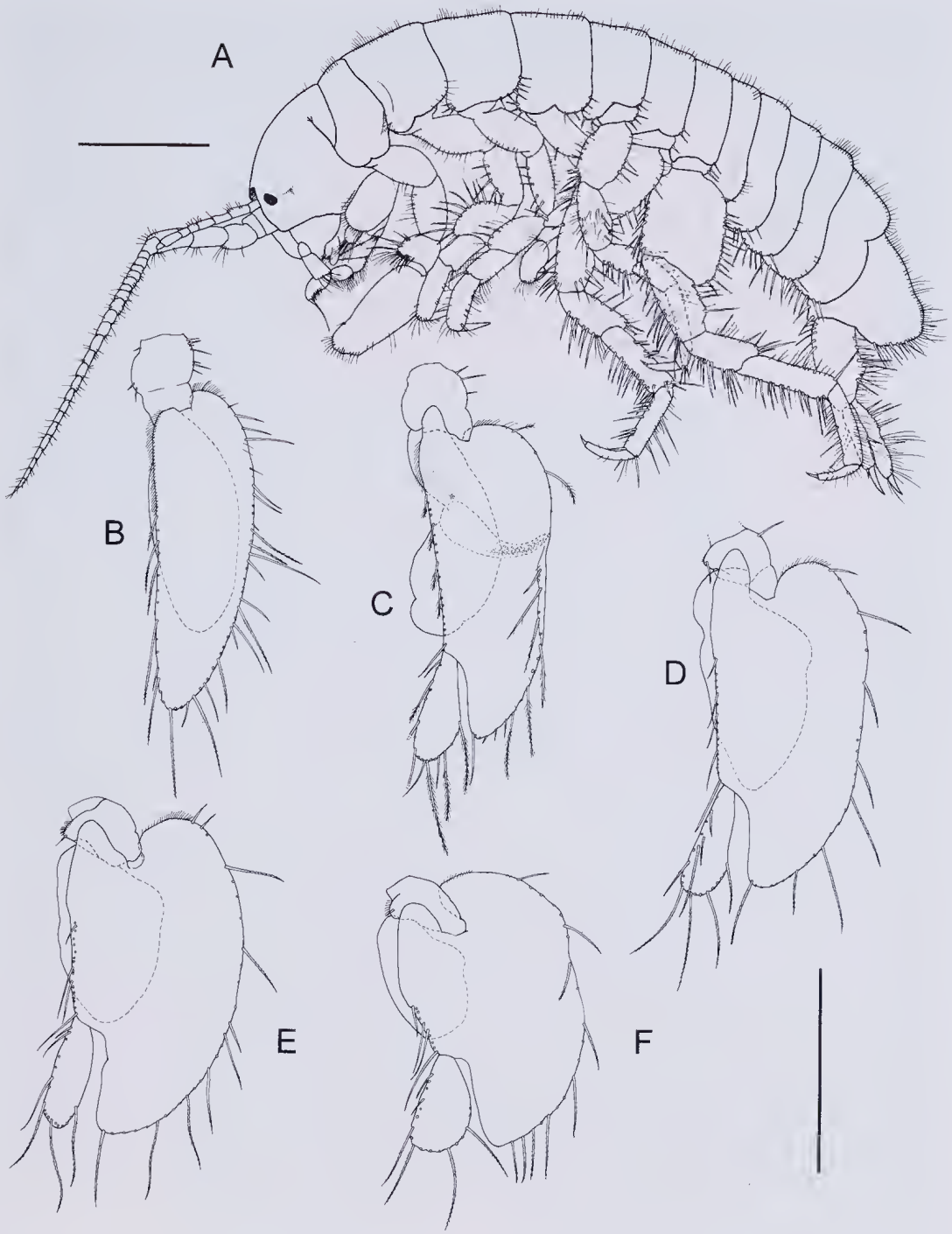

FIG. 7. *Ponderella ecomanufactia* gen. et sp. nov. A, lateral view, holotype ♂, QM W26730; scale bar 2mm. B-F, pleopods I-V, ventral view, ♂, AM P64014; scale bar 1mm.

sexes of *P. ecomanufactia* have propodal articular plates on the posterior pereopods V-VII; these are missing in *P. bundoona*. The shape and relative setation of the pereopod VII bases are distinct (compare Figs 6C and 11D) and are useful for separating the two species in a sample. The shape and setation of the pleotelson also differ considerably between the two species, with *P. ecomanufactia* having a less inflected dorsal profile and many more setae on the posterior margin. The two species are so different that they might be assigned to separate genera were more species known from this clade. Based on the current knowledge of this clade, however, we do not create two monotypic genera that would be phylogenetically redundant with the species-level taxa. No new information is added by creating separate genera, so the species can stand for any superspecific hypothesis.

Ponderella species are apparently restricted to a small area of southwestern Queensland, in environmentally degraded springs (W. Ponder, pers. comm.). Similar springs in New South Wales and South Australia have become extinct (e.g., Hergott Bore, the type locality for *Phreatomerus latipes*), and as water resources are increasingly depleted in the arid western regions of Queensland, we are concerned that these two species could become critically endangered. Exploratory activity throughout the Great Artesian Basin may find additional populations of *Ponderella*, but for the moment we assume that they are extremely narrow range endemics. Because they represent a unique morphology among the Phreatoicidea, like many of the other taxa in the group, they afford considerable phylogenetic diversity to the areas where they occur. To preserve this diversity, immediate efforts are needed to protect the springs in which these isopods occur.

Ponderella bundoona sp. nov.
(Figs 1-6)

'Qld n sp.2': Wilson & Edgecombe, 2003: 455, 464, fig.14.

ETYMOLOGY. "*bundoona*" is derived from Bundoona Homestead Springs, and is used as a noun in apposition.

TYPE MATERIAL. Holotype: QM W26732, ♂ bl 6.6mm, "Bundoona" Homestead springs, Queensland, 27°57.15'S 144°46.21'E, 0-1.6m depth, in flowing water at spring head and outflow (15-20 cm from spring head), W.F. Ponder & C. Lydeard, 2 May 2001, QMS-4, #51805. Paratypes: same collection data as holotype - AM P64020, ♂ bl 9.0mm; AM P64021, ♂ "B" bl 6.7mm; AM P64022, ♀ bl 4.7mm; AM P64023, ♂ "A"; AM P64024, ♀ bl 5mm; AM P64025, 3 ind.; AM P64026, ♂ "C"; QM W26733, 2 ♀♀, ♂; AM P64027, 13 ind.; AM P64028, ♂ bl 6.3mm; AM P64019, many ind. Other collections near "Bundoona" Homestead springs, Queensland, Australia, AM numbers: P64029, on mud and submerged vegetation from edges of spring and in water, W.F. Ponder & C. Lydeard, 2 May 2001; P66836-7, main spring, outflow area, edges of spring, deeper pools with sedges, W.F. Ponder, J.H. Waterhouse & A.C. Miller, 4 April 2002.

OTHER MATERIAL. Collections by W.F. Ponder, J.H. Waterhouse & A.C. Miller, 4-6 April 2002, Springs on Bundoona Homestead (sites near 27°57.12'S 144°46.15'E), Queensland, AM numbers: P68023, head of small spring flowing into pool, near main spring, seepage; P68024, body of small spring flowing into pool, near main spring; P68025, area around head of spring, mostly on thick wet mud, out of water flow; P68026, head of spring, on wet sand, mostly out of water flow; P68027, main flow area, seepage/flow areas of spring, short sedges & duck weed; P68028, main body of spring, still pool with lots of duck weed & sedges; P68029, head of spring, on mud & in water; P68046, main flow area, seepage/flow areas of spring, short sedges and duck weed; P68047, from edges of spring, deeper pools with sedges; P68031-4 and P68048-9, pools west of road to Quilpie (27°56.48'S 144°46.70'E), on & in mud & on vegetation, both in & out of water. Near Eulo township, Queensland, Australia, spring west of Paroo River (28°09.5'S 145°02.8'E), AM P68030, in small pools and lower outflows, mostly under grasses in mid section of mound.

DIAGNOSIS. Head, lateral margin above mandibles with row of elongate thin setae. Pleotelson lateral length less than depth, dorsal margin in lateral view with major inflection differentiating apex from dorsal surface; posterior margin with no elongate thin setae. Antenna short, length 0.3-0.38 body length. Mandible incisor process short, not extending to level of spine row; right lacinia mobilis tiny, scale-like, not extending to base of first spine in spine row. Percopods propodus I-VII articular plate absent in both sexes; dactylus I in male projecting subequal to palm; propodus I palm in male with strong medial spine; carpus IV in male ventral margin not flattened laterally; basis VII dorsal plate strongly convex, almost circular; margin with many elongate fine setae; propodus V-VII distally truncate; dactylus V-VII thin, spine-like, shorter than most distal propodal setae. Pleopod protopods III-V with narrow, lobe-like lateral epipods. Uropod protopod distoventral margin with 5 robust spinose setae.

DESCRIPTION (MALE). *Coloration.* Patches of brown on head, clypeus, labrum, antennules and antenna, otherwise opaque white in ethanol.

Head. (Figs 1A, 2A-B) Length shorter than width in dorsal view; setae in row along ventral margin, fine. Eyes maximum diameter 0.12 head depth;

FIG. 8. *Ponderella ecomanufactia* gen. et sp. nov. A, head, dorsal and lateral, ♀, AM P64013. B-C, antennula and antenna, ♂, AM P64012. D, maxillula with enlargement of lateral lobe in medial view, ♂, AM P64011. E, maxilliped, ventral view, ♂, AM P64014. Scale bars 0.5mm.

approximately round; ocelli distinguishable as individual units. Cervical groove (weakly) extending just above antero-lateral margin of pereonite 1. Mandibular groove absent.

Pleonites. (Fig. 1A) 1-4 relative lengths subequal, width 0.62 composite length in dorsal view.

Pleotelson. (Fig. 6E-F) Dorsal length 1.16 width; lateral length 0.13 body length, 0.93 depth; depth 1.63 pereonite 7 depth; margin anterior to uropods 0.53 width of uropodal insertion. Posterolateral margin with distinct inflection differentiating apex; projecting in lateral view; apex compressed anteriorly.

Antennula. (Fig. 2A,D) Length 0.14 body length, with 7 articles. Article 6 with 2 aesthetases, 1 on article 7, all tiny.

Antenna. (Fig. 2) Article 5 shorter than article 4. Flagellum length 0.51 total antenna length, with 13 articles.

Mouthfield. (Figs 2A-B, 4A) Clypeus width 0.61 head width.

Mandible. (Fig. 3) Palp length 0.68 mandible length; 3rd article relatively linear. Left spine row with 10 spines, 7 of which bifurcate. Right spine row with 9 spines, 7 of which bifurcate.

Maxillula. (Fig. 4B) Medial lobe length 0.89 lateral lobe length; width 0.91 lateral lobe width; with 1 'accessory' seta between medial pappose setae, simple. Lateral lobe with 6 denticulate robust setae.

Maxilla. (Fig. 4C) Medial lobe width 0.69 outer lateral lobe width.

Maxilliped. (Fig. 4D) Endite distal tip with 20 (approximately) subdistal biserrate setae on ventral surface; medial margin with 2 coupling hooks on left side, 1-2 on right side (1 short coupling hook, longer setae distally with cusps half way along, similar to cusps on receptaculi); dorsal ridge with 11 large distally denticulate plumose setae (proximal setae not noticeably denticulate and distal setae not noticeably plumose). Palp insertion on basis ventral surface with 5 subdistal smooth setae.

Pereopod I. (Fig. 5A) Propodus dorsal margin with 10 setae altogether (excluding distal group); propodus palm ridge present, without setae; basis ventrodistal margin with multiple elongate setae. Pereopod IV (Fig. 5E) dactylus distal accessory claw absent; propodus with 2 broad-based setae on ventral margin (and 3 additional fine setae), 1 distinctly larger than remainder.

Penes. (Fig. 6D) Length 0.27 body width at pereonite 7.

Pleopods. (Fig. 1B-F) Protopods medial margins I with epipod, II-V with small projections. Pleopod II endopod appendix masculina basal musculature pronounced; with 19-25 setae on margin; length 0.37 pleopod length.

Uropod. (Fig. 6E-G) Total length 1.64 pleotelson length. Protopod length 0.48 uropod total length. Endopod shorter than protopod, dorsal margin with 1–6 robust setae (1–2 dorsally at midpoint, 3–4 distally). Exopod length 0.88 endopod length; dorsal margin with 3 robust setae.

SEXUAL DIMORPHISM, FEMALE DIFFERENCES. Antenna flagellum with 11 articles. Pereopod I (Fig. 5C) dactylus projecting beyond palm; ventrodistal margin with row of sharp spines distally, thin scale-like spines proximally, along 0.55 total length. Propodus dorsal margin proximal region not protruding. Propodal palm concave proximally, straight distally; simple spines absent, with finely serrated composite spines along length; setal ridge absent. Uropod total length 1.56 pleotelson length. Endopod with 4-7 robust setae (4 dorsally, 3 distally). Exopod dorsal margin with 2-6 robust setae (2 dorsally, 4 distally).

DISTRIBUTION. "Bundoona" Homestead springs and springs to the west of Paroo River, near Eulo Township, Queensland, Australia.

Ponderella ecomanufactia sp. nov.
(Figs 7-12)

'Qld n sp.1': Wilson & Edgecombe, 2003: 455, 464, fig.14.

ETYMOLOGY. For the Eco Manufacturing Centre of Fuji Xerox Australia.

TYPE MATERIAL. Holotype: QM W26730, ♂ bl 7.8mm, "Bundoona" Homestead springs, Queensland, 27°57.15'S 144°46.21'E, 0-1.6m depth, in flowing water at spring head and outflow (15-20cm from spring head), W.F. Ponder & C. Lydeard, 2 May 2001, QMS-4, #51805. Paratypes: same collection data as holotype - AM P64011, ♂, specimen 1; AM P64012, ♂, specimen 2; AM P64013, ♀, specimen 3; AM P64014, specimen 4; AM P64015, ♀, specimen 5; QM W26731, 2 ♀♀, 1 ♂; AM P64016, 2 ind.; AM P64010, 14 ind. Nearby collections by W.F. Ponder & C. Lydeard, 2 May 2001, AM P64017, on mud and submerged vegetation from edges of spring and in water. Nearby collections by W.F. Ponder, J.H. Waterhouse & A.C. Miller, April 2002, AM P66838-9, main spring, outflow area, edges of spring, deeper pools with sedges.

OTHER MATERIAL. Collections by W.F. Ponder, J.H. Waterhouse & A.C. Miller, during April 2002. Springs on Bundoona Homestead (near 27°57.12'S 144°46.15'E), Queensland, AM numbers: P68050, main spring, main flow area, seepage/flow areas of spring, short sedges and duck weed; P68051, except from edges of spring, deeper

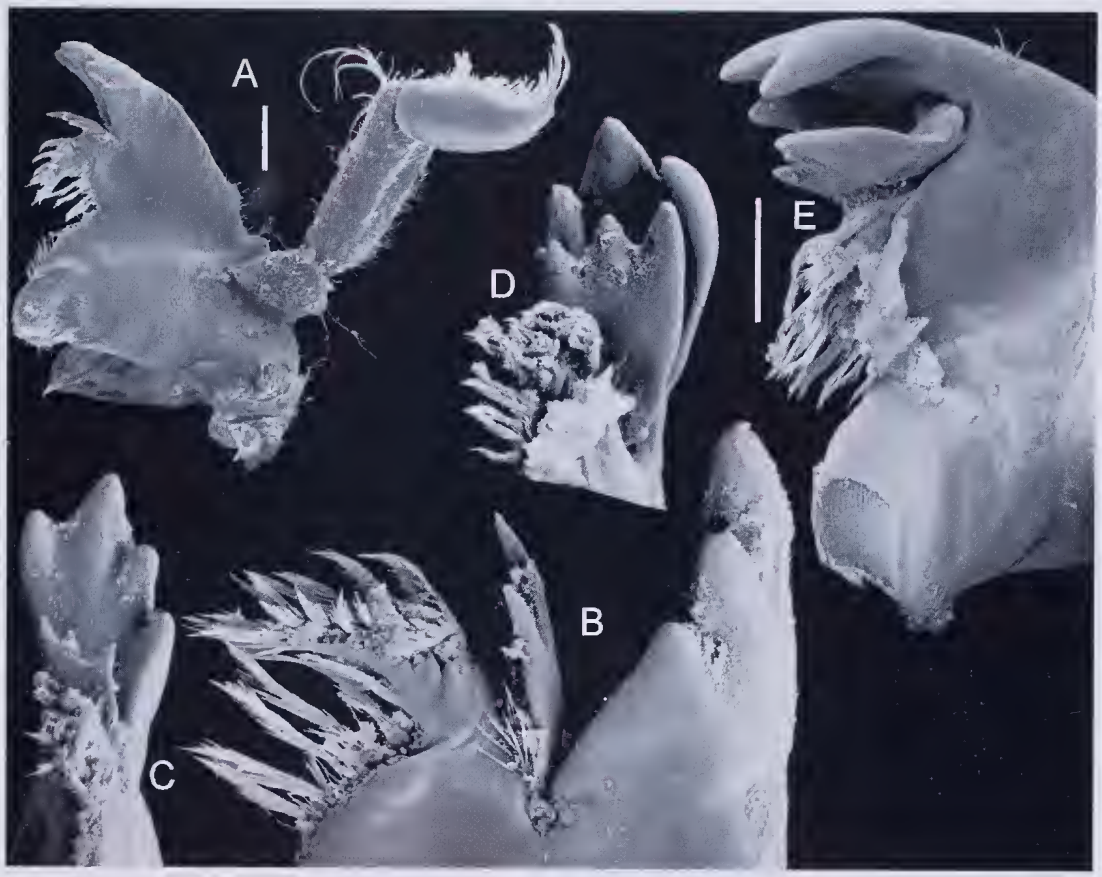

FIG. 9. *Ponderella ecomanufactia* gen. et sp. nov. ♂, AM P66838. A-C, right mandible, dorsal view, with enlargement of distal tip, dorsal and medial views. D-E, left mandible, medial enlargement of distal tip and ventral view of gnathal edges. Seale bars, 0.1mm.

pools with sedges; P68035, head of small spring flowing into pool, near main spring, seepage; P68036, body of small spring flowing into pool, near main spring; P68037, main spring, area around head of spring, mostly on thick wet mud, out of water flow; P68038, main spring, head of spring, on wet sand, mostly out of water flow; P68040, main spring, main body of spring, still pool with lots of duck weed & sedges; P68041, on mud & in water; P68043-5, west of road to Quilpie (27°56.48'S 144°46.70'E), on & in mud & on vegetation, both in & out of water. Near Eulo Township, Queensland, Australia, spring to the west of Paroo River (28°09.51'S 145°02.17'E), AM numbers: P64018, in small pools and lower outflows; P68042, in & on mud (some out of water), mostly under grasses in mid section of mound.

DIAGNOSIS. Head lateral margin above mandibles with only scattered tiny setae, row of elongate thin setae absent. Pleotelson lateral length subequal to depth, dorsal margin in lateral view without major inflection in margin differentiating apex; posterior margin with many elongate thin setae. Antenna long, length 0.49-0.62 (male, female, respectively) body length. Mandible incisor processes normal length, extending to level of spine row; right lacinia mobilis large, extending to level of first spine in spine row. Pereopods propodus articular plates II-III absent, IV in male present, but absent in female, V-VII present in both sexes; dactylus I in male projecting beyond palm; propodus I palm with low rounded medial spine; carpus IV in male ventral margin produced into laterally flattened rounded plate; basis VII dorsal plate weakly convex, almost sublinear; margin with short simple setae; propodus V-VII distally tapering; dactylus V-VII basally broad and tapering distally, longer than most distal propodal setae. Pleopod protopods III-V without lateral epipods. Uropod protopod distoventral margin without robust spinose setae, with 4 robust simple setae.

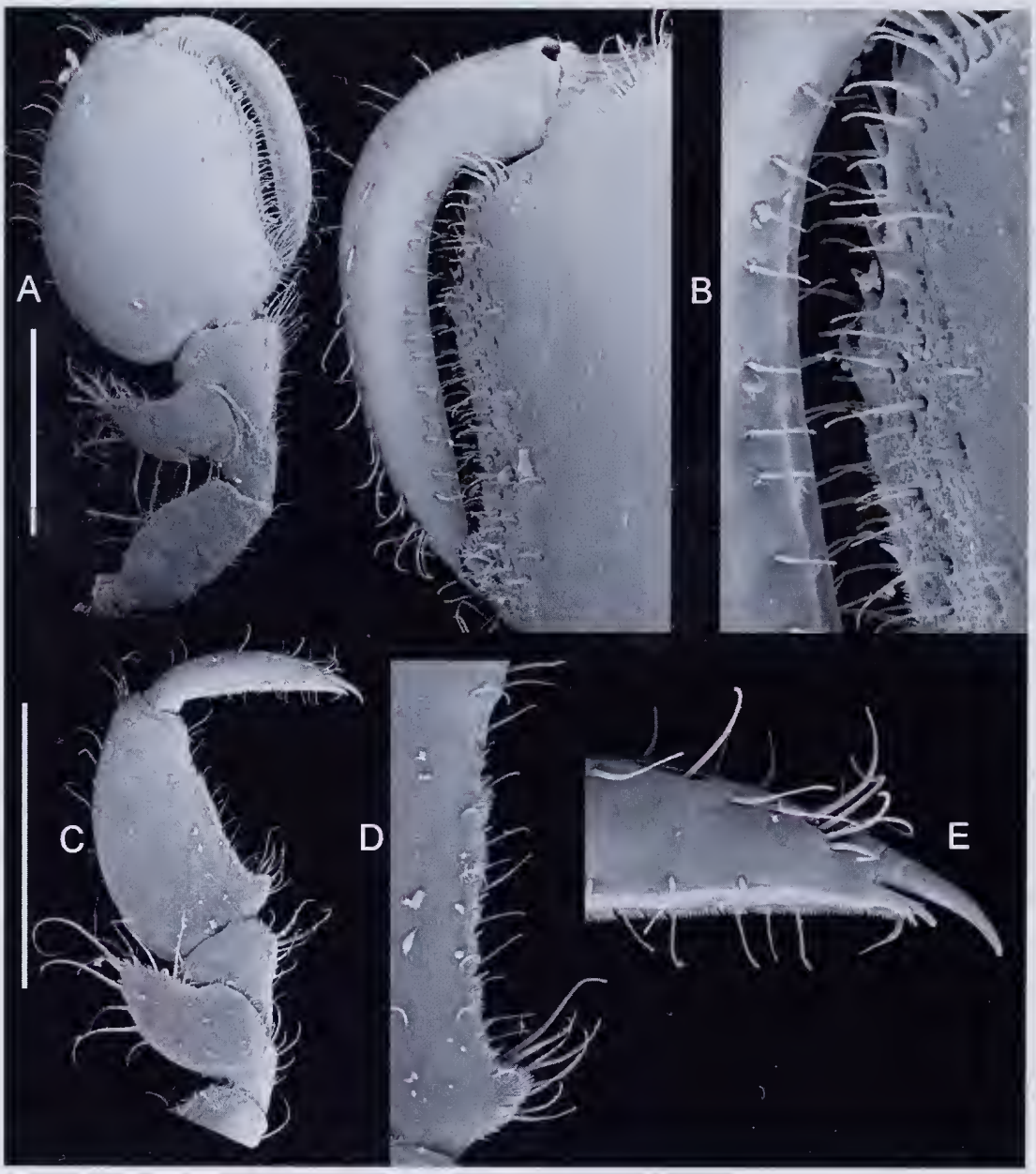

FIG. 10. *Ponderella ecomanufactia* gen. et sp. nov. A-B, pereopod I, right lateral view and enlargements of palm in medial view, ♂, AM P64011. C-E, pereopod I, right lateral view of distal segments with enlargements of the propodal palm and dactylus distal tip, ♀, AM P64013. Scale bars 0.5mm.

DESCRIPTION (MALE). *Coloration* tan to dark brown dorsally and anteriorly, pereopods lighter, in ethanol.

Head. (Fig. 8A) Length subequal to width in dorsal view; setae sparse. Eyes maximum diameter 0.13 head depth; approximately triangular (apex ventral); ocelli not distinguishable as individual units. Cervical groove straight, extending nearly to dorsal margin of head. Mandibular groove smoothly indented.

FIG. 11. *Ponderella ecomanufactia* gen. et sp. nov. A-B, pereopods II and IV, left lateral view, ♂, AM P64011. C, pereopod IV, right lateral view, ♀, AM P64013. D-E, pereopod VII, left lateral view with enlargement of dactylus and articular plate, ♂, AM P64014. Scale bars 0.5mm.

Pleon. (Fig. 7A) Pleonites 1-4 relative lengths unequal, increasing in length from anterior to posterior, width 0.79 composite length in dorsal view.

Pleotelson. (Fig. 12A-B) Dorsal length 1.39 width; lateral length 0.14 body length, 1 depth; depth 1.5 pereonite 7 depth; margin anterior to uropod length 0.48 uropod insertion length. Posterolateral margin uninterrupted (without major inflection in margin differentiating apex).

Antennula. (Fig. 8A-B) Length 0.13 body length, with 8 articles. Article 6 with 1 aesthetasc, 3 on article 7, 1 on article 8, all tiny.

Antenna. (Fig. 8C) Article 5 length subequal to article 4. Flagellum length 0.75 total antenna length, with 27 articles.

Mouthfield. Clypeus width 0.55 head width; paragnaths margin broadly curving, lateral setal rows sparse (observations from AM P64014).

Mandible. (Fig. 9) Palp length 0.85 mandible length; 3rd article crescent-like. Left incisor process with 1 small denticle on dorsal margin. Left spine row with 12 spines, 5 of which bifurcate (approximately). Right spine row with 12 spines, 5 of which bifurcate.

Maxillula. (Fig. 8D) Medial lobe length 0.77 lateral lobe length; width 0.88 lateral lobe width; without 'accessory' setae. Lateral lobe with 7 denticulate robust setae.

Maxilla. Medial lobe width 0.77 outer lateral lobe width.

Maxilliped. (Fig. 8E) Endite distal tip with multiple subdistal biserrate setae on ventral surface; medial margin with 4 coupling hooks on left side, 4 on right side; dorsal ridge with 14 large distally denticulate plumose setae (proximal setae not noticeably denticulate and distal setae

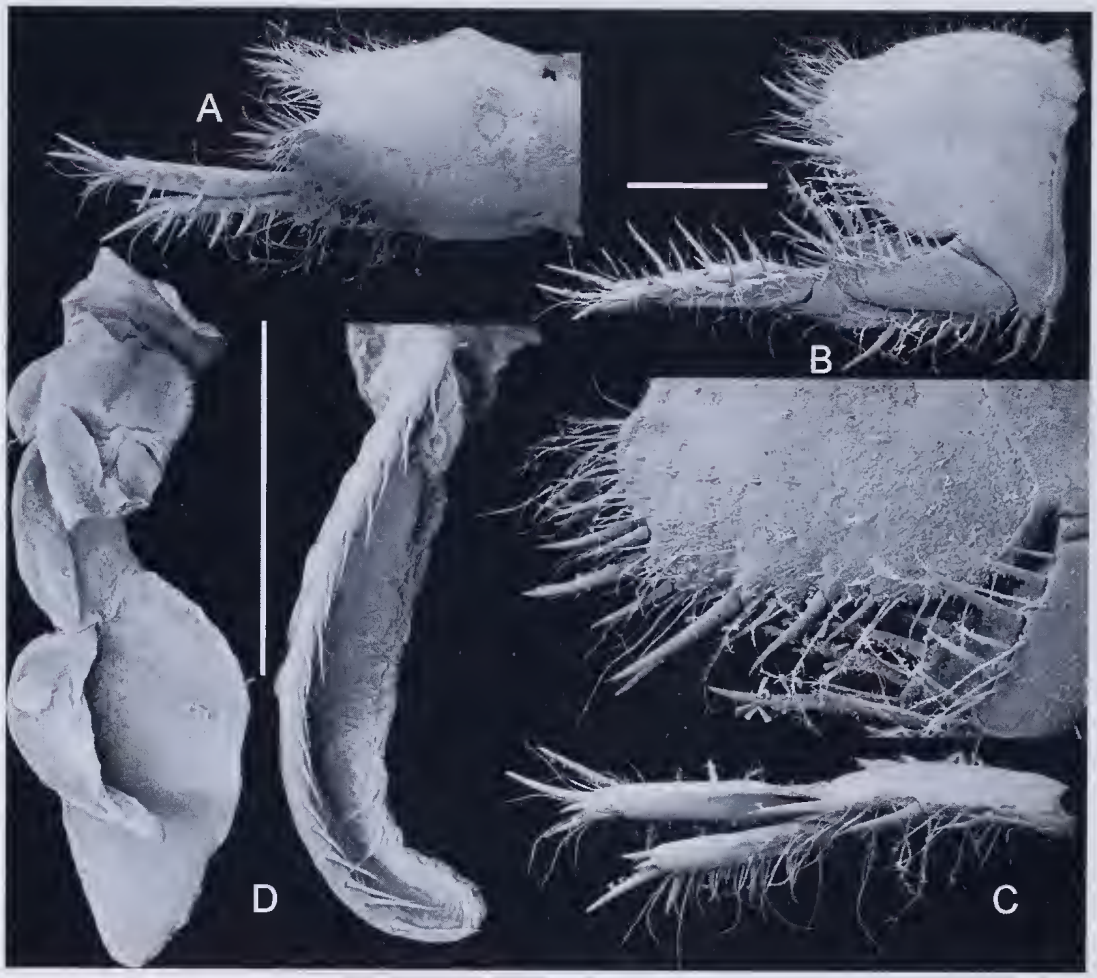

FIG. 12. *Ponderella ecomanufactia* gen. et sp. nov. ♂, AM P64011. A-B, pleotelson, dorsal and lateral views; C, uropod, left ventral view. D, pleopod II endopod and enlargement of appendix masculina. Indentation and wrinkling in the uropod are drying artefacts. Scale bars 0.5mm.

not noticeably plumose). Palp insertion on basis ventral surface without subdistal smooth setae.

Pereopod I. (Figs 10A-B, 11B) Propodus dorsal margin with 15 setae altogether (excluding distal group); propodus palm setal ridge absent; basis ventrodistal margin with 1 elongate seta. Percopod IV dactylus distal accessory claw present, propodus with 4 broad based setae on ventral margin (about 11 other fine setae on margin), 2 distinctly larger than remainder (grading in size from 2 smaller setae); articular plate in male on posterior side of limb shorter than dactylar claw.

Penes. Length 0.32 body width at pereonite 7.

Pleopods. (Fig. 7B-F) Protopods medial margin III-V with epipods. Pleopod II endopod appendix masculina basal musculature not pronounced; with 38 setae on margin; length 0.25 pleopod.

Uropod. (Fig. 12B-C) Total length 1.82 pleotelson length. Protopod length 0.34 uropod total length. Endopod subequal to protopod length; dorsal margin with 9–11 robust setae. Exopod length 0.8 endopod length; dorsal margin with 6 robust setae.

SEXUAL DIMORPHISM, FEMALE DIFFERENCES. Antennula with 7 articles. Antenna flagellum with 24 articles. Pereopod I (Fig. 10C-E) subchelate (but propodus much narrower than male, tending toward simple). Dactylus

length subequal to palm; ventrodistal margin with multiple rows of minute sharp spines, along 0.62 total length. Propodal palm simple spines absent, with 1 large proximal finely serrated composite spine and smaller finely serrated composite spines along length. Uropod total length 1.48 pleotelson length. Protopod length 0.43 uropod total length. Endopod with 7 robust setae.

DISTRIBUTION. "Bundoona" Homestead Springs and springs to the west of Paroo River, near Eulo Township, Queensland, Australia.

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LITERATURE CITED

CHOPRA, B. & TIWARI, K.K. 1950. On a new genus of phreatoicid isopod from wells in Banaras. Records of the Indian Museum (Calcutta) 47(3/4): 277-289.

DALLWITZ, M.J., 1980. A general system for coding taxonomic descriptions. Taxon 29: 41–46.

DALLWITZ, M.J., PAINE, T.A. & ZURCHER, E.J. 2000a. User's guide to the DELTA editor. http://biodiversity.uno.edu/delta/.

2000b. User's guide to the DELTA system: a general system for processing taxonomic descriptions. Edition 4.12, December 2000. (CSIRO: Canberra).

KNOTT, B. & HALSE, S.A. 1999. *Pilbarophreatoicus platyarthricus* n. gen., n. sp. (Isopoda: Phreatoicidea: Amphisopodidae). Records of the Australian Museum 51(1): 33-42.

NICHOLLS, G.E. 1943. The Phreatoicoidea. Part I. The Amphisopidae. Papers and Proceedings of the Royal Society of Tasmania 1942: 1-145.

1944. The Phreatoicoidea. Part II. The Phreatoicidae. Papers and Proceedings of the Royal Society of Tasmania 1943: 1-156.

NICHOLLS, G.E. & MILNER, D.F. 1923. A new genus of fresh-water Isopoda, allied to *Phreatoicus*. Journal of the Royal Society of Western Australia 10(6): 23-34.

PONDER, W.F. 1986. Mound springs of the great artesian basin. Pp. 403-420. In De Deckker, P. & Williams, W. D. (eds) Limnology in Australia. (CSIRO: Melbourne and Dr W. Junk Publishers: Dortrecht).

2004. Endemic aquatic macroinvertebrates of artesian springs of the Great Artesian Basin - progress and future directions. Records of the South Australian Museum Monograph Series 7: 101-110.

PONDER, W.F. & CLARK, G.A. 1990. A radiation of hydrobiid snails in threatened artesian springs in western Queensland. Records of the Australian Museum 42: 301-363.

SAYCE, O.A. 1900. *Phreatoicoides* a new genus of freshwater Isopoda. Proceedings of the Royal Society of Victoria 12: 122-138.

1902. A new genus of Phreatoicidae. Proceedings of the Royal Society of Victoria 14: 218-224.

SHEPPARD, E.M. 1927. Revision of the family Phreatoicidae (Crustacea), with a description of two new species. Proceedings of the Zoological Society of London 1927: 81-124.

SPENCER, B. & HALL, T.S. 1896. Description of a new genus of terrestrial Isopoda, allied to the genus *Phreatoicus*. Proceedings of the Royal Society of Victoria 9(3): 12-21.

WILSON, G.D.F. & EDGECOMBE, G.D. 2003. The Triassic isopod *Protamphisopus wianamattensis* (Chilton) and comparison with extant taxa (Crustacea, Phreatoicidea). Journal of Paleontology 77: 454-470.

WILSON, G.D.F. & KEABLE, S.J. 1999. A new genus of phreatoicidean isopod (Crustacea) from the North Kimberley Region, Western Australia. Zoological Journal of the Linnean Society, London 126(1): 51-79.

2001. Systematics of the Phreatoicidea. In Kensley, B.F. & Brusca, R.C. (eds) Isopod systematics and evolution. Crustacean Issues 13: 175-194. (A.A. Balkema: Rotterdam).

2002a. New genera of Phreatoicidea (Isopoda, Crustacea) from Western Australia. Records of the Australian Museum 54: 41-70.

2002b. New Phreatoicidea (Crustacea: Isopoda) from Grampians National Park, with revisions of *Synamphisopus* and *Phreatoicopsis*. Memoirs of Museum Victoria 59: 457-529.

SPOTTED-TAILED NORTHERN QUOLLS, *DASYURUS HALLUCATUS*: A PRECAUTIONARY TALE. *Memoirs of the Queensland Museum 49(2): 760. 2004*:- All Quoll, *Dasyurus* species are characterised by their pale-spotted pelage. Only the Spotted-tailed or Tiger Quoll *Dasyurus maculatus*, is acknowledged as having spots on its tail as well as its body, and this is used as a defining characteristic of the species in all field guides and reference works (e.g. Strahan, 1995; Queensland Museum, 2000; Menkhorst, 2001). In this note we report upon the prevalence of spotted tails on Northern Quolls *D. hallucatus* from a population at Cape Cleveland (147°03E˚ 19°16'S), near Townsville, north Queensland and within the collections of the Queensland Museum. No specimens from the Northern Territory or Western Australia have been examined.

Nineteen *D. hallucatus* (15 females: 4 males) were live trapped at Cape Cleveland during 120 trap nights during 1-4 June 1999. Of these, 5 females had spotted tails. The spots on these tails were typical of the dorsal and lateral spots on the body of *D. hallucatus*, being for the most part small and fleck-like compared to larger and more prominent spots on *D. maculatus*. The spotting was none-the-less obvious when the animals were being handled and in 2 cases while still in the trap, prior to handling. In 3 of the 5 spotted-tailed individuals, the spotting consisted of 1 or 2 small but discrete white flecks on the dorsal and/or lateral surface about mid-way down the tail. In 2 other individuals, 2 conspicuous spots occurred on the dorsal and lateral surface of the tail at its base and about mid-way down its length respectively.

Of 37 dry and spirit specimens of *D. hallucatus* in the Queensland Museum 7 (3 males, 3 females and one unsexable specimen), also exhibited spotting on the base and midway along their tails, similar to that described above. These spotted-tailed individuals originated from Gympie (SE Qld), Walkamin, Shiptons Flat, and the Cooktown area (NE Qld). The paratype of *D. h. predator*, locality Cape York Peninsula, is also among these spotted-tailed individuals.

While the extent of spotting on the tails of these *D. hallucatus* is not nearly as intense or prominent as the tail spotting of *D. maculatus* (Fig. 1), spotted tails are not unique to *D. maculatus*. Field guides need to take this into account to avoid misidentification of Northern and Spotted-tailed Quolls. With experience, the two quoll species are easily distinguished on the basis of body size, patterning and head shape, however to the uninitiated, the length of the pes provides an infallible method for identification of the 2 species. In *D. maculatus* pes length (measured from the back of the heel to the end of the longest toe but not including the nail), is never less than 57mm (n = 53), in *D. hallucatus* never more than 51mm (n = 26).

Acknowledgments

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Literature cited

MENKHORST, P.A. 2001. Field guide to the mammals of Australia. (Oxford University Press: South Melbourne).

QUEENSLAND MUSEUM, 2000. Wildlife of tropical north Queensland.(Queensland Museum: Brisbane).

STRAHAN, R (ed.) 1995. The mammals of Australia. (Reed Books/Australian Museum: Sydney).

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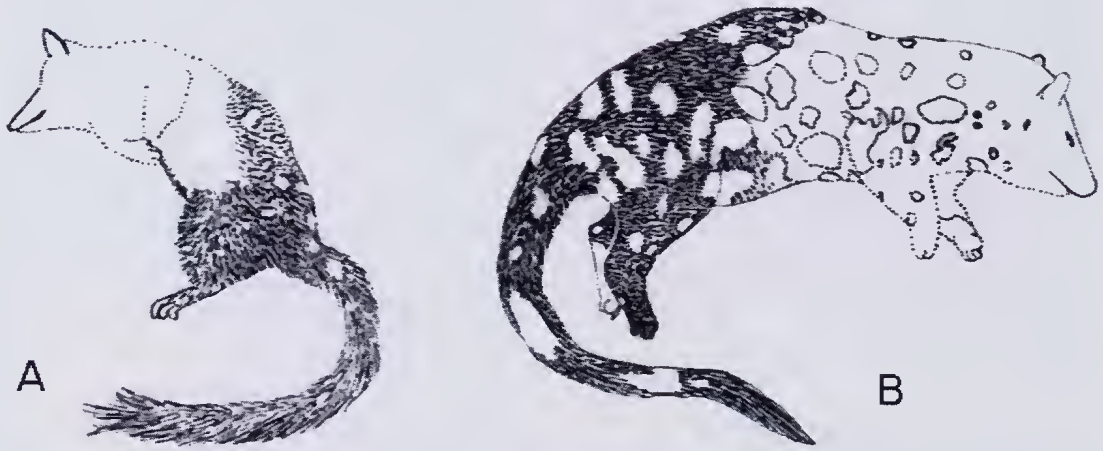

FIG. 1. Tails of (A) *D. hallucatus* and (B) *D. maculatus* showing the nature of spotting in both species. Drawings taken from photographs of anaesthetised quolls captured on the Mt Windsor Tableland, north Queensland.

OCCURRENCE OF *SMINTHOPSIS VIRGINIAE VIRGINIAE* (TARRAGON, 1827) AND *RATTUS LEUCOPUS COOKTOWNENSIS* (TATE, 1951) IN NORTH QUEENSLAND SUGARCANE AREAS. *Memoirs of the Queensland Museum 49(2): 761-762. 2004*:- Small mammal research in coastal North Queensland since the 1940s has concentrated on the control of *Rattus sordidus* (Gould, 1858) and *Melomys burtoni* (Ramsay, 1887) as agricultural pests in sugarcane. Redhead (1973), Hitchcock (1973), Wilson & Whisson (1993) and Story (1990, 1993a, 1993b) examined rodent populations and formulated management strategies. In particular, Wilson & Whisson (1993) and Wbisson (1996) demonstrated that non-rodenticidal methodologies can be successful in reducing population numbers. None of these studies, however, have investigated the utilisation of sugarcane crops by other non-target small mammal species or quantified the effects of rodenticides on such species.

Sminthopsis virginiae virginiae (Tarragon 1827), the red-cheeked dunnart, is seldom seen in sugarcane. Redhead (pers. comm.) recorded one specimen in the Abergowrie region, Herbert River district (18°28'S 145°50' E) in 1972 . The specimen was trapped in sugarcane adjacent to open sclerophyll forest with an understorey dominated by blady grass (*Imperata cylindrica*), spear grass (*Heteropogon contortus*) and kangaroo grass (*Themeda triandra*).

This paper documents *S. virginiae virginiae* and *R. leucopus cooktownensis* in sugarcane in the Herbert Valley and Tully cane growing regions of north Queensland.

Herbert Valley

Elliott Type A small mammal traps baited with cardboard squares soaked in linseed oil were set in a 40 trap grid (4 cane rows of 10 traps each with each trap 10m apart) within a cane field in the Lannercost area of the Herbert Valley (18°33'S 146°01'E). Head-body, tail, hind foot and ear measurements, sex and body weight were recorded. Individual animals were processed and released at the point of capture.

Weed biomass was assessed at each site where *R. leucopus cooktownensis and S. virginiae virginiae* were collected. Five sampling points distributed throughout the cane field were allocated a biomass rating of 0, 1, 2, 3 or 4 corresponding to percentage green cover expressed as 0, 1-25, 26-50, 51-75 and 76-100% respectively. A mean weed index was calculated for each site as the average of the value for the 5 sampling points.

Tully

Elliott Type A live traps baited with a mixture of peanut butter, rolled oats and vanilla essence were used. Eight lines of 6 Elliott traps, 10m apart, and bordered by 6 cage traps, were laid in the Euramo area (18°01'S 145°52'E). Sex class classification and weed biomass sampling was as in the Herbert Valley. Animals were processed and released at the point of capture.

Results

In the Herbert Valley, Nov. 1993-June 1994, 5 *S. virgineae* were captured ; they had body lenghts 93-118mm,tail lengths 84-105mm and weights38-64 g. 2 more were captured during the Tully trials Aug-Dec. 1994.

During 2 trappings in August and October 1994 in the Tully region, 11 and 18 *R. leucopus* were captured with head-body length 113-162mm, tail length 113-155mm and weight 62-210gm.

R leucopus cooktownensis were caught in cane fields devoid of in-crop weeds (Table 1). These cane fields had low populations of *R. sordidus*, probably due to low weed levels (Wilson & Whisson, 1993).

Discussion

R. sordidus and *M. burtoni* are common in sugarcane and their ability to quickly colonise cane fields and establish territories probably allows them to exclude less fecund species. *R. sordidus and M. burtoni* are strongly "r" selected (MacArthur & Wilson, 1967) exhibiting high fecundity and colonisation rates. *S. virginiae virginiae* and *R. leucopus* have lower fecundity, are less strongly selected for "r" characteristics and therefore it is unlikely that this species would utilise temporary habitats as successfully as *R. sordidus* and *M. burtoni*. So why would *S. virginiae virginiae* and *R. leucopus* utilise a temporary habitat such as a cane field?

Green cane harvestingof sugarcane began in the Herbert Valley in the early 1980's increasing from 7 to 26% of the crop during 1985 (Wood 1986). Since 1985 green cane harvesting and trash blanketing practices have been widely adopted with 98.9% of all cane at the Victoria Mill and 97.6% of cane at the Macknade Mill cut green (BSES annual report 1994).

Robertson (1990) indicated that green cane harvesting, which returns crop residues to the soil surface, has a positive effect on earthworm populations. Increasing earthworm numbers under sugarcane has the potential to improve plant residue decomposition, nutrient cycling, soil aeration, soil-water infiltration, to stimulate crop growth and to increase soil aggregate strength (Robertson 1990). Robertson (1990) also stated that 'termites have a similar role to earthworms in the tropics and are common in Central Queensland crops grown with no tillage techniques where crop residues are left undisturbed on the soil surface'.

Robertson (et al. 1993) documented differences in invertebrate functional groups (i.e. herbivores, predators and detritivores) in zero tilled and conventional cultivated agricultural systems over 5 years. It was noted that zero tillage agro-ecosystems generally had the highest levels of detritivores and predators, while the conventionally cultivated systems had relatively low abundances of these groups. Robertson (et al. 1993) suggested that the retention of crop residues on the soil surface in zero tillage situations favours decomposer and predatory soil organisms. They found that the density of predators was correlated with the density of detritivores in zero tillage.

The ecological diversity of an agricultural system is restricted compared to native habitats which have a more complex array of species and ecological functional groups with a greater degree of trophic level interactions. In promoting the re-establishment of invertebrates, biodiversity will be increased and with it an increase in fauna predacious on invertebrates. Given that *S. virginiae virginiae* mainly eats insects, it follows that a likely explanation for the occurrence of this species in sugarcane is the increased levels of invertebrate biodiversity brought about by green cane harvesting.

R. leucopus cooktownensis individuals appeared to comprise a distinct colony within the cane field as opposed to the patchy distribution of *R sordidus* (Wilson & Whisson, 1993). Recaptures were common on successive nights indicating the colony was relatively stable at the time of sampling. *R. leucopus cooktownensis* samples were caught in a cane field with no weeds (Table 1) and therefore unsuitable for *R .sordidus* which depends on in-crop weed biomass to trigger their breeding cycle (Wilson & Whisson 1993). This may have allowed *R. leucopus cooktownensis* to colonise this cane field and establish territories. The Cape York rat is a shy and unobtrusive species (Watts & Aslin, 1981) and may not defend territory against *R. sordidus*. *R. leucopus cooktownensis* has a largely insectivorous diet with some fungi, fruit and nuts also eaten (Watts and Aslin 1981). Therefore the hypothesis that increasing the invertebrate biodiversity of the sugarcane agricultural system using green cane harvesting and trash retention techniques may provide a food source for higher order predators, may also apply for *R. leucopus cooktownensis* in sugarcane.

Until recently fauna found in sugarcane fields was poorly understood. With the exception of occasional fauna surveys (Lavery & Grimes 1976) little interest was paid to fauna in sugarcane that was not of economic significance. Incidental observations such as those described in this publication indicate that sugarcane may be a habitat for numerous species not originally thought to be of ecological significance. The registration of agricultural chemicals, whether insecticides, rodenticides or herbicides, must be evaluated for a wider range of non-target and secondary species hazards. Soil insecticides and fumigants interfere with the already disrupted biodiversity in cane fields and could result in further loss of soil fauna diversity. The benefits of a diverse soil fauna include the potential to improve plant residue decomposition, nutrient cycling, soil aeration, soil-water infiltration, to stimulate crop growth and to increase soil aggregate strength (Robertson, 1990).

Although the numbers of animals caught and the subsequent data analysis presented here are insufficient for a detailed look at the population dynamics of these two species in relation to sugarcane production, the occurrence of *R. leucopus cooktownensis* and *S. virginiae virginiae* in north Queensland sugarcane fields suggest a closer look at the interaction between changed agricultural techniques such as green cane harvesting and crop residue or trash blanket retention, and native Australian fauna is warranted. Alterations to the biodiversity of invertebrates as a result of sugarcane production may lead to populations of larger, insectivorous vertebrates such as *R. leucopus cooktownensis* and *S virginiae virginiae* being sustained in sugarcane fields.

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References

HITCHCOCK, B.E. 1973. An evaluation of aerial baiting for the control of rats in cane fields. Proceedings of the Australian Society of Sugarcane Technologists 40th conference pp 59-64

KREBS, C. J. 1985. Ecology: the experimental analysis of distribution and abundance, 3rd ed (Harper and Row: New York).

LAVERY, H.J. & GRIMES, R. 1976. Mammals and birds of the Ingham district, north Queensland 1. Introduction and mammals. Queensland Journal of Agricultural Animal Science 31: 383-90.

MACARTHUR, R.H. & WILSON, E.O. 1967. The theory of island biogeography. (Princeton University Press: Princeton).

REDHEAD, T.D. 1968. Rodent control in Queensland sugarcane. In Proceedings of the Asia Pacific Interchange, June, pp 37-42 .

1973. A reassessment of the rat problem in north Queensland canefields with emphasis on the ecology and reproduction of *Melomys littoralis* (Lonnberg). *Msc Thesis, James Cook University.*

ROBERTSON, L.N. 1990. Agriculture and the ecosystem in north Queensland. In Proceedings of a symposium of the north Queensland sub-branch of the Australian Institute of Agricultural Science, AIAS Occasional Publication 51, 1990, pp. 56-64 (Norman, K.L. & Garside, A.L. eds)

ROBERTSON, L.N., KETTLE, B.A. & SIMPSON, G.B. 1993. The influence of tillage practices on soil macrofauna in a semi-arid agro-ecosystem in north-eastern Australian. *Agriculture, Ecosystem and Environment*, 48, pp 149-156

STORY, P.G. 1990. A rodent monitoring program for the Tully Mill district. Bureau of Sugar Experiment Stations internal report.

1993a. The evaluation of Klerat® for use against *Rattus sordidus* in the Queensland sugar industry. Bureau of Sugar Experiment Stations Research Report 93001.

1993b. Addition of the aversion agent Bitrex® does not impede consumption by rodents in sugarcane. *Bureau of Sugar Experiment Stations Research Report 93002.*

STRAHAN, R. (ed.) 1995. The complete book of Australian mammals. (Angus and Robertson: Sydney).

WATTS, C.H.S. & ASLIN, H.J. 1981. Rodents of Australia. (Angus and Robertson: Sydney).

WHISSON, D. 1996. The effect of two agricultural techniques on populations of the canefield rat (*Rattus sordidus*) I sugarcane crops of north Queensland. *Wildlife Research* 23(5):589-604.

WILSON, J. & WHISSON, D. 1993. Rodent management in north Queensland sugarcane. Sugar Research and Development Corporation Funding Report.

WOOD, A.W. 1986. Green cane trash management in the Herbert Valley. Preliminary results and research priorities. Pp. 86-94. In Proceedings of the Australian Society of Sugarcane Technologists 53rd Conference.

P.G. Story, Australian Plague Locust Commission, GPO Box 858, Canberra ACT 2601 (p.story@affa.gov.au); 15 1 04

TABLE 1. Relative mean weed biomass in cane fields where *Rattus leucopus* were captured.

	Weed biomass index	*R. leucopus* captured
August 1994	0.0	0
	2.2	0
	0.0	11
	0.0	0
October 1994	0.0	13
	1.2	0

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